**FINAL DRAFT**

Revision 3 (May 16, 1990)

# MONITORING AND OPERATING PLAN FOR C-111 INTERIM CONSTRUCTION PROJECT

PERMIT # 131654749

Submitted to

Florida Department Environmental Regulation

By

South Florida Water Management District

Project Manager: Dewey F. Worth

Enivironmental Sciences Division
Department Research and Evaluation

**FINAL DRAFT**

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## 1.0 INTRODUCTION

The Interim C-111 Plan has evolved from numerous public meetings and comments by interested persons and professional staff of various state and federal agencies. A major focus of concern has been the recurring environmental disturbance associated with removal of the earthen plug at S-197, the terminal outfall for the C-111 canal.

Operating criteria for the S-197 structure have also evolved with changing demands throughout the basin. Although this structure was originally constructed by the Corps as a temporary measure to prevent salt water intrusion, flood control demands on the system have required the full outlet capacity of the C-111 canal. Plug removal has occurred due to the necessity to satisfy flood control demands for existing development in South Dade County.

At the request of the District, the U.S. Army Corps of Engineers has undertaken a re-evaluation of the C-111 Basin through the General Design Memorandum (GDM) process to correct environmental and flood control deficiencies. As an "intermediate" solution, the District proposed an interim plan to reduce environmental impacts associated with the plug removal while maintaining existing levels of flood control. Applications for federal, state and local permits were subsequently filed for construction. To date, permits have been obtained from the Florida Department of Environmental Regulation (Permit # 131654749, issued November 3, 1989), U.S. Army Corps of Engineers (Permit # 89IPC-20492 issued March 12, 1990) and by Dade County Department of Environmental Resource Management (Permit # __________, approved by the Dade County Commission January 16, 1990).

Permit conditions issued by the Florida Department of Environmental Regulation (DER) and Dade County Department Environmental Resource Management (DERM) require the District to develop a monitoring and operation program in cooperation with other regulatory agencies. The District is specifically required to perform the following:

1) within six months of issuance of the DER permit (May 16, 1990), coordinate one or more interagency meetings to discuss issues, develop criteria under which discharges will be performed, develop monitoring criteria to assess impacts of discharge from the structures, and a schedule for implementation; and

2) within six months prepare and submit to the Bureau of Wetland Resource Management in Tallahassee a plan of operation for structures and monitoring of the effects of the discharge which reflects the interagency coordination effort. Upon approval of the above plan by the Department, the monitoring plan will be included in the permit as a formal modification.

DER permit special conditions further stipulate that the Interagency Committee be composed of the following agencies:

Florida Department of Natural Resources (DNR)
Florida Department of Environmental Regulation (DER)
U.S. Army Corps of Engineers (Corps)
Dade County Department of Environmental Resource Management (DERM)
U.S. Fish and Wildlife Service (FWS)
Everglades National Park (ENP)
South Florida Water Management District (District)

Responsibility of the Interagency Committee will be to review and recommend an operation and monitoring program as outlined above. It is further recommended that the committee serve as an advisory panel at the end of a two year test period to review and recommend specific changes in operating criteria and other structural modifications.

Additional special conditions required by the U.S. Army Corps of Engineers (COE) specifically require the District conduct a feasibility study of the U.S. Fish and Wildlife Service proposed culvert and spreader canal demonstration project for C-111E. Correspondence concerning this concept is included as Appendix 1.

## 1.1. Interagency Committee Meetings

Interagency Committee meetings were held on November 29, 1989 and March 21, 1990 as required under the above permit conditions. Tables 1 lists the agencies contacted and the representatives in attendance. Draft operation and monitoring plans were circulated to members for their review prior to each of the formal meetings. Written comments were also requested concerning modifications to the draft proposals or other items of concern. Proposed operation/monitoring plans were presented and reviewed at each of the committee meetings and other alternatives discussed. A summary of the agenda and discussion items are included in Appendix 2 together with written responses/comments that were received.

## 1.2. Document Scope

This document proposes specific operational and monitoring criteria to meet objectives as discussed at the Interagency meetings and required by permit conditions. The operating and monitoring requirements consist of two phases. Phase I consist of a two year experimental program and will be implemented with construction of S-197 and G-211. After analysis of hydrologic data and other monitoring information, Phase II of a construction and monitoring program will be implemented. Phase II will include specific modifications to the C-111 gaps and continuation/revision of monitoring programs initiated under Phase I.

TABLE 1. INTERAGENCY COMMITTEE MEETINGS.

| PARTICIPATING AGENCIES | AGENCY REPRESENTATIVES | |
|---|---|---|
| | NOVEMBER 29, 1989 | MARCH 21, 1990 |
| U.S. Army Corps of Engineers | John Hashtak, Planning<br>Mike Choate, Hydrology<br>Lewis Hornung, Projects<br>John Moulding, Ecologist | -Representatives Did Not Attend - |
| S. Florida Water Management District | Walt Dineen, Env. Sciences<br>Cal Neidrauer, Basin Plan<br>Ron Bearzotti, Proj. Manag.<br>Paul Whalen, Env. Plan.<br>Shawn Sculley, Water Res.<br>Tom MacVicar, Exec. Office<br>Dan Haunert, Env. Planning<br>Sara Bellmund, Env. Plan.<br>Dewey Worth, Env. Plan. | Ronald Mierau<br>Cal Neidrauer<br>Ron Rearzotti<br>Bob Chamberlain<br>Shawn Sculley<br>Scott Thorp<br>Dan Haunert<br>Sara Bellmund<br>Dewey Worth<br>John Adams |
| Everglades National Park | Jim Tilmant, Estuarine Res.<br>Bob Johnson, Hydrology<br>Mike Soukup, Dir. Research<br>John Ogden, Wildlife Res. | Jim Tilmont<br>Bob Johnson |
| U.S. Fish & Wildlife | David Ferrell, Regulatory<br>Arnold Banner, Wildlife Res. | Arnold Banner |
| U.S. National Marine Fisheries | Joan Browder, Fisheries | Joan Browder |
| Fla. Department Environmental Reg. | Herb Zebuth, Reg. Review | Herb Zebuth |
| Fla. Dept. Game Fish Commission | Dan Dunford, SE Region Dir. | |
| Fla. Dept. Natural Resources | - Did Not Attend - | George Henderson |
| Dade County Dept. Env. Resource Mangmt. | Carlos Espinosa, Regulatory<br>Wayne Richter, Regulatory | Rick Alleman<br>Eric Meyers |
| Fla. Department Transportation | | Rory Santana<br>Laura Brinkley |
| Dade County Plan./ Water and Sewer | | Jean Elroy<br>Celia Rozas |

## 2.0 PROJECT AREA

The project area is located in southern Dade County Florida. Figure 1 shows the location of basins, canals, structures and other major features within the project area. Modifications or improvements to structures are proposed for specific portions of the South Dade County Conveyance System that affect basins C-1 and C-111 (Figure 1). Proposed changes include replacement of the existing S-197 structure and addition of a new structure in the L-31N canal (Figure 2). Operational changes are also proposed that will affect water deliveries for ENP Taylor Slough (Figure 1).

## 3.0 C-111 INTERIM PLAN OBJECTIVES

Objectives of the C-111 plan are to 1) reduce the duration of large discharge events at S-197 associated with removal of the earthen plug, 2) increase the frequency and distribution of flow to the Everglades National Park Panhandle by increasing flow through the gaps in the C-111 canal, 3) raise the canal stage in L-31N between S-335 and C-1W to reduce seepage into L-31N canal and enhance the hydroperiod in Northeast Shark River Slough, and 4) maintain current level of flood protection. These objectives will be accomplished by specific structural additions and/or changes in operation criteria that include the following:

1) Add culverts to S-197 - Increase the number of gated culverts from 3 to 13; Addition of 10 - 84 inch gated culverts and re-construction of more stable earthen plug.

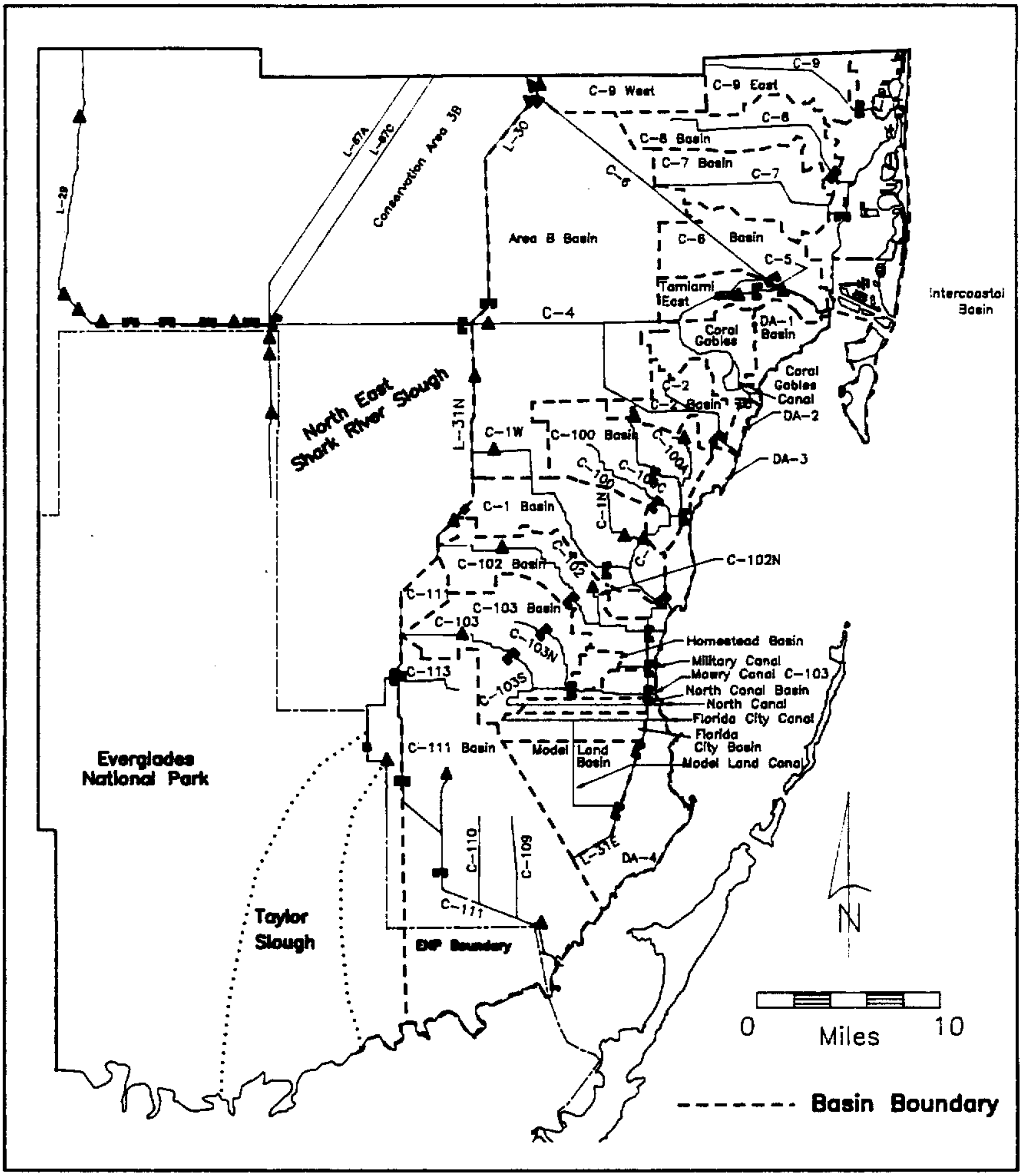


Figure 1. Generalized diagram of south Dade County with canals, structures and major features

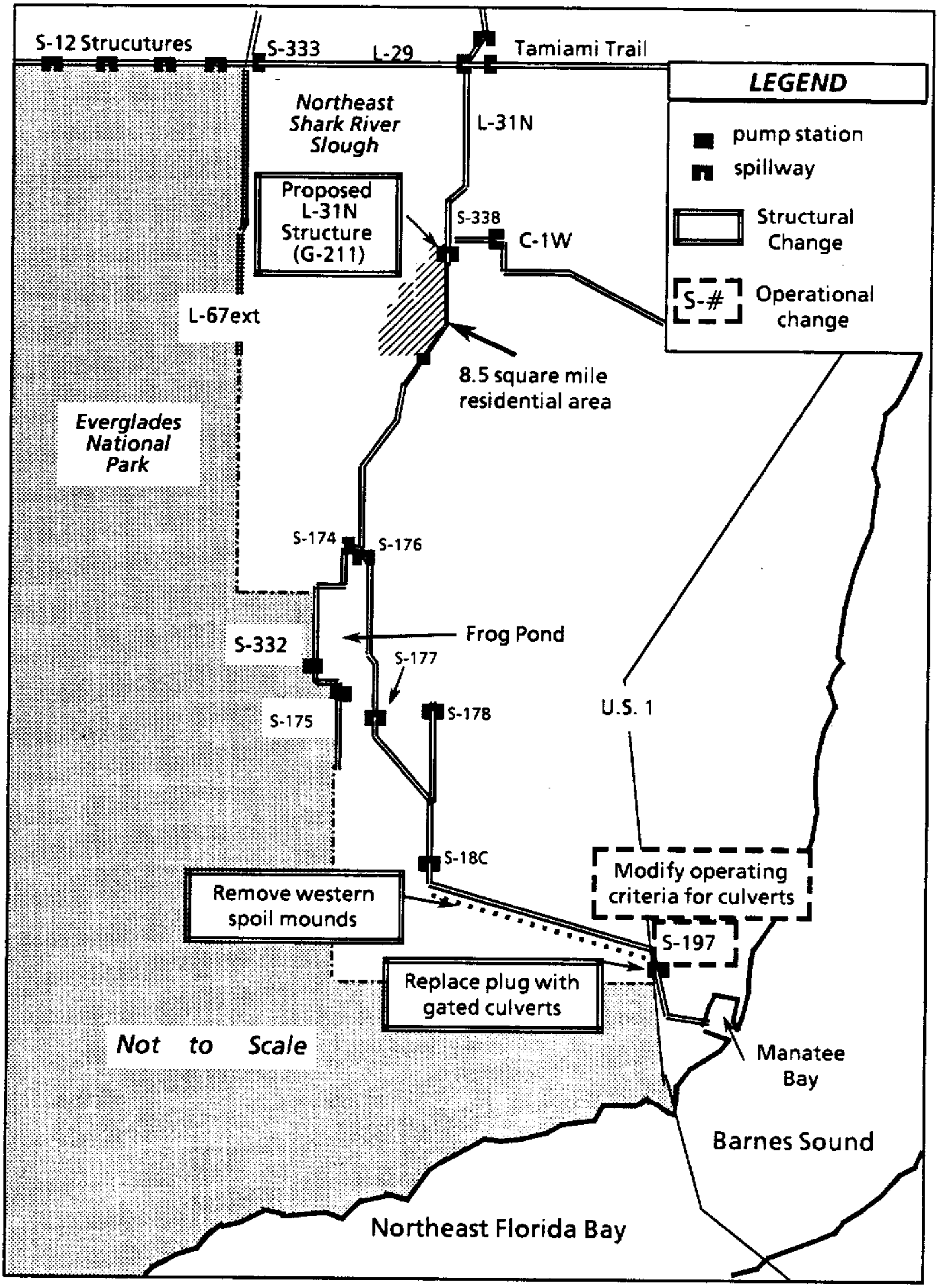



Figure 2. Generalized diagram of C-111 basin with location of proposed changes.

2) Modify Gaps in C-111 South Levee - Modify cross section area of C-111 gaps to enhance flow of water to ENP Eastern Panhandle.

3) Install new structure G-211 - Addition of a new gated culvert in the L-31N canal immediately south of the junction of the L-31N canal and C-1W.

Objectives associated with the Interim Plan are independent from the COE C-111 GDM and were not advocated as a replacement or substitution for issues associated with the federal project design.

## 4.0 OPERATIONAL STRATEGY

The above modifications are intended to alter the volume, timing and distribution of water discharged from C-111 while maintaining adequate levels of flood control. Proposed changes will affect hydrology and hydraulics related to distribution of runoff during storm events and also modify distribution of routine water deliveries (flows not related to major storm events) to Taylor Slough and ENP Eastern Panhandle. In addition, installation of the new structure in L-31N (G-211) will increase ground water stage control in Northeast Shark River Slough immediately upstream of the structure and reduce seepage to the L-31N canal. Options to distribute any seepage entering the L-31N canal upstream of the new structure (G-211) are discussed in Section 4.2.2. Table 2 lists the desired water levels to be maintained under wet season conditions for specific canal segments within the project area.

Operating and monitoring criteria as specified in this plan will be followed for the first two years after completion of the S-197 and G-211 construction. At the conclusion of this initial two year test period and following analysis of the hydrology data, the Interagency Review Committee may evaluate and recommend alternative operating criteria that will enhance the environment without compromising flood control.

The District has recently proposed an experimental water delivery program for Taylor Slough (see Appendix 3 and section 4.2.3). This plan would modify the existing scheduled delivery of water to Taylor Slough with one based on local rainfall. The proposed plan includes adding pumping capacity at S-332 to divert more water from the L-31W canal directly to Taylor Slough. This additional operating flexibility has been integrated into the operating schedule of the C-111 Interim Plan. Any additional permits that may be required for implementation of the Taylor Slough experimental plan will be acquired separate from the existing permit.

**Table 2. Flood Control Operating Conditions for Canals and Structures in the C-111 Project Area*.**

| Canal Location | Canal Reach | Control Structure | Flood Control Stage (NGVD)@ |
|---|---|---|---|
| Upper L-31N | S-335 to G-211 | G-211 | 5.5 - 6.0 + |
| Middle L-31N | G-211 to S-173 | S-331/S-173 | 4.5 - 5.0 # |
| Lower L-31N | S-173 to S-176 | S-176 | 5.2 @@ |
| L-31W | S-174 to S-175 | S-174<br>S-175 | 5.0<br>4.5 - 5.0 ** |
| Upper C-111 | S-176 to S-177 | S-177 | 4.2 |
| Middle C-111 | S-177 to S-18C | S-18C | 2.6 |
| Lower C-111 | S-18C to S-197 | S-197 | see Sec.4.1.1 |

* Information based on current and proposed changes in operating practices, SFWMD Dept. Operations and Maintenance

@ Flood control stage is the maximum stage allowed in the canal before mandatory flood control releases are triggered. In some instances, such as S-331/S-173, criteria require the structures to be closed.

+ Proposed canal stage upstream of new structure. When canal stage at S-176 exceeds 5.5 ft NGVD <u>or</u> when S-173 tailwater exceeds 6.0, S-173/S-331 will be closed. If the water level downstream (south) of G-211 is greater than the headwater (north) of the structure, G-211 will be opened full to allow drainage to C-1W (see Sec. 4.1.2.). S-173/S-331 are also closed if heavy rainfall is forcast in the area and the tailwater at S-173 is 5.0 ft. Dry season canal stages may be maintained at a lower level.

# Stage level depends on water level at Angels well located in residential area west of L-31N. If Angle's well is between 5.5-6.0, the S-331 pump is turned on and canal headwater is held at 5.0; if Angel's well is above 6.0, the S-331 pump is turned on and canal headwater is held at 4.5 ft. Structure is closed reguardless of the levels at Angel's well when flooding potential downstream at S-173/S-331 appears as described in note (+) above.

@@ Flood control stage has previously been adjusted seasonally using 4.5 during wet season (June 1 to Oct. 31) and 5.0 during the dry season (Nov 1 to May 31). New criteria will use 5.2 as the flood control stage throughout the year. The new criteria will allow water to be diverted by gravity through S-174 or released through S-176, depending on the stage conditions in L-31W.

** Due to the flat topography of the area and short length of the L-31W canal, a slope in the canal water profile must be sustained between S-175 and S-174 in order to effectively move water from L-31N into the L-31W canal. Operation of the S-175 structure will be regulated to allow more frequent diversion of water from L-31N when water supply is available (see section 4.2.3).

## 4.1. Operations During Major Storm Events

### 4.1.1 S-197 Operation

During major storm events, S-197 will continue to function as the primary flood control outlet for the C-111 basin. However, the cumulative number days the S-197 structure is operated and the cumulative volume of runoff discharged will be reduced compared with historical conditions. The priority of operation will be to discharge excess water through the gaps and Taylor Slough (according to the proposed rainfall plan, see attachment 3) until such time that critical stage criteria at S-18C or S-177 are exceeded. Culverts at S-197 will then open according to appropriate stage schedules as described in Table 4.

Due to the temporary design of S-197, there are physical and logistical constraints that limit flexibility in the operation of the culverts. Each culvert is designed with a single movable steel plate that allows the structure to be fully opened or closed. Intermediate or partial openings are not possible. Canal hydraulics also influence the number of culverts that can effectively be opened or closed to regulate canal water levels within a specific range. Opening too few culverts could allow canal stage levels to continue rising above recommended flood control levels and potentially trigger full opening of all culverts at S-197 when this action might otherwise be unnecessary. Conversely, opening too many culverts will lower C-111 canal stage and reduce the rate of discharge through the C-111 gaps (or promote overdrainage), particularly in the western portion of the canal where ground elevations at the gap openings are higher than gap elevations to the east.

The proposed suite of culvert operations and corresponding canal stages that trigger specific actions were selected based on the above limitations. However, these criteria are preliminary since operation of the system, with the scheduled modifications, has not been tested. Some level of operational experience will be required to define what limits exist in the range of flexibility under these new conditions. Changes in operation criteria at S-197 to further reduce the duration or frequency of culvert openings may be recommended after additional experience has been gained with the project improvements.

Table 3. Flood Control Operating Conditions for S-197 Structures in the C-111 Canal. Reference to water level data is in NGVD.

**OPEN CULVERTS:** Opening of S-197 culverts will begin when water levels exceed specified levels at the referenced structures:

S-177 HW* > 4.10 after gates have been opened full** or S-18C HW > 2.80: open 3 culverts

S-177 HW > 4.20 for 24 hours or S-18C HW > 3.10: open 7 culverts

S-177 HW > 4.30 or S-18C HW > 3.30: open 13 culverts

**CLOSE CULVERTS:** Closing of the culverts at S-197 will begin after the following conditions have been met:

1) When headwater canal stage (stage upstream of the structure) at S-176 has declined below 5.2 ft NGVD **and** headwater stage at S-177 has declined below 4.2 ft NGVD. Stage levels above 5.2 ft and 4.2 ft respectively, at these structures trigger mandatory flood control releases. A declining trend in water levels below this stage would indicate the peak of the storm event has passed.

2) position of the storm has moved away from the basin

3) once conditions 1 and 2 above have been met, only the number of S-197 culverts required to match the residual discharge volume flowing through S-176 will remain open. This will prevent unnecessary over drainage of the panhandle region by restricting the amount discharged through S-197 to equal the amount of inflow from the upper basin. All culverts will be closed once the S-177 headwater stage declines below 4.1 ft NGVD and the above conditions are satisfied.

* HW = Head water stage upstream of the structure

** Due to the discharge capacity of S-177, headwater stage levels upstream of this structure may decline abruptly once the structure is opened. Culverts at S-197 will remain closed until S-177 has been completely opened. This lag time will allow the canal levels to equalize and provide an opportunity for flood waters to first discharge through the C-111 gaps. After the S-177 gates have been fully opened and canal stage level continues to exceed the flood control criteria, culverts at S-197 will be opened according to the above criteria.

### 4.1.2 Storm Operations for Structures G-211, S-331/S-173 and S-338

The new structure G-211, located in the L-31N canal and immediately south of the confluence of C-1W, will require special operating conditions during storm events. C-1W canal is the primary conveyance canal for the C-1 Basin (Figure 3). During major storm events, S-173 and S-331 are operated as a drainage divide to prevent flood flows in the C-1 basin from flowing south into the C-111. Current operating criteria for S-331/S-173 require these structures be closed whenever headwater stage at S-176 increases above 5.5 NGVD or if tailwater at S-331 exceeds 6.0 NGVD. Excess runoff collected in the L-31N canal upstream of S-331/S-173 is then directed east through S-338 to the C-1W canal. To allow for continued flood protection of the L-31N canal segment between S-173 and the new structure G-211, operating criteria for G-211 will require this structure be opened whenever high stages downstream force the closing of S-331/S-173. Flood waters will then be allowed to discharge north through G-211 and east through S-338 into C-1W as before. Storm operating criteria for S-331/S-173, S-338 and S-176 will remain unchanged.

### 4.1.3. Storm Operation of L-31W and S-332 Pumping to Taylor Slough

Under storm events, a portion of the local runoff entering L-31N will first be diverted to the L-31W canal through S-174 and pumped to Taylor Slough by the S-332 pumping station, or discharged through S-175. Pumping at S-332 will continue at the maximum capacity of the structure (including proposed rainfall

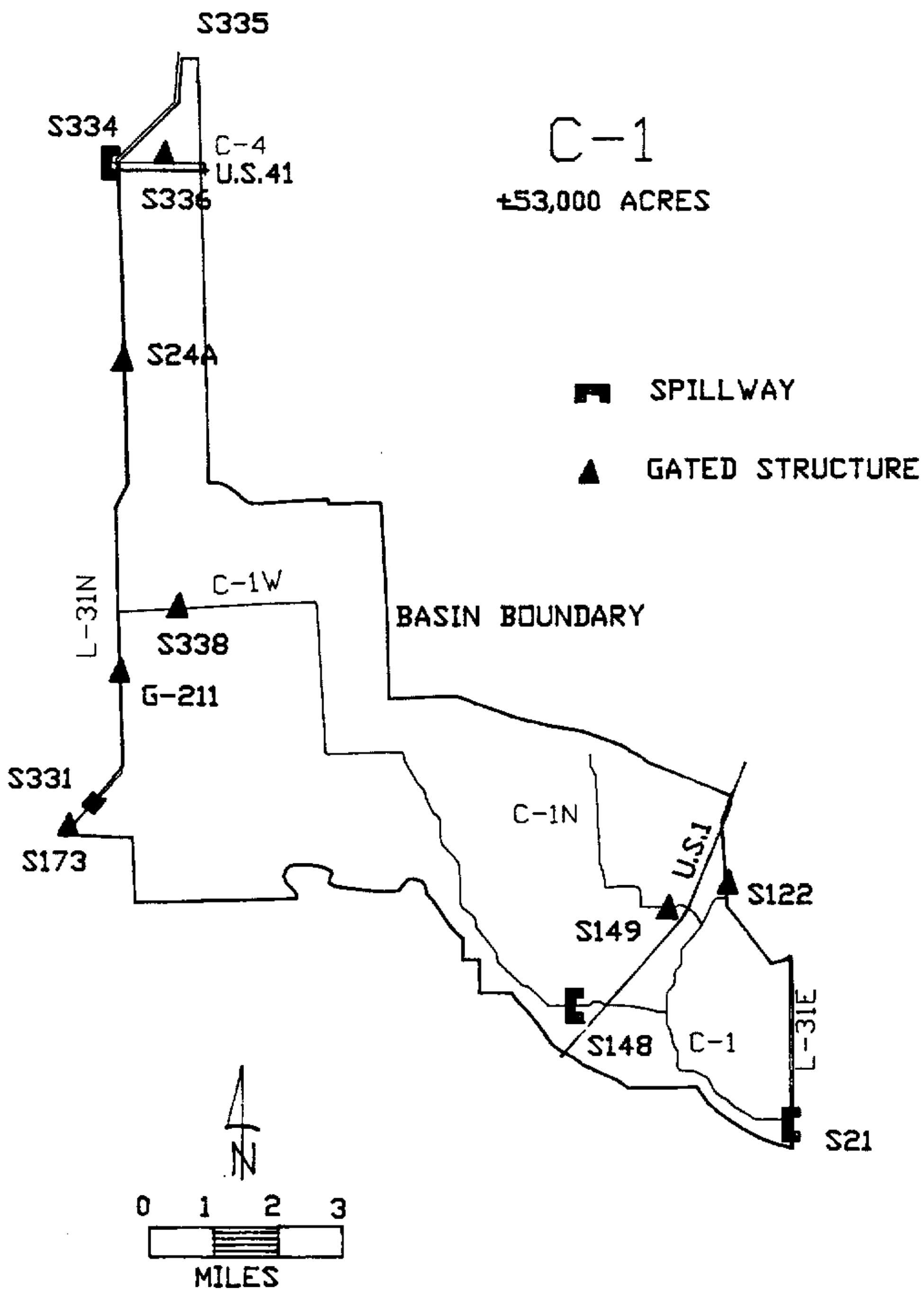



FIGURE 3. CONVEYANCE CANALS AND STRUCTURES IN THE C-1 BASIN.

modifications, see Section 4.2.3.) until one of the following conditions are met: 1) the S-176 structure is closed, or 2) until pumping operation is modified as indicated by the rainfall formula when adopted, or 3) in accordance with recommendations after consultation between District Operations personnel and ENP staff at the time of the particular rainfall event. Normal pumping activities at S-332, as required to meet scheduled water supply deliveries to Taylor Slough, will resume once any of the above conditions have been satisfied. Since pending modifications proposed under the Interim C-111 Plan will significantly alter existing rainfall/runoff characteristics of the basin, the amount or magnitude of the rainfall event defined as a storm event is intentionally ambiguous at this time. Guidelines will be developed in consultation with the ENP and District staff to better define operational practices at the conclusion of the initial two year study.

## 4.2. Routine Water Supply Operations

### 4.2.1 S-197 Water Supply Operation

Under routine operating conditions (those conditions not dominated by major storms), the S-197 structure will remain closed to encourage flow through the C-111 gaps. The specific modifications to the gaps, the number to be modified and their location will be determined based on field monitoring data and recommendations by the review committee. Data collection efforts to define the appropriate modifications for the C-111 gaps are described in section 5.1.6.

### 4.2.2 Operation of Structures G-211 and S-338

Construction of G-211 creates several options to control excess runoff from small rainfall events and seepage collected in the L-31N canal upstream of the proposed new structure. Selection of the alternatives will be guided by downstream stage conditions. The priority of alternatives will be as follows: 1) discharge a portion of the seepage or runoff collected upstream of the G-211 through the structure, then through S-331/S-173, S-174 and finally through S-332 to supplement flow to Taylor Slough. The amount of local runoff diverted to Taylor Slough would be guided by the rainfall plan (see attachment 2), 2) continue diverting a portion of L-31N seepage through S-176/S-177/S-18C and the gaps in C-111 to supplement flows to the ENP Eastern Panhandle, and 3) divert any remaining seepage through S-338 to the C-1W canal.

### 4.2.3. S-332 Taylor Slough Diversion/Water Supply

Water supply for Taylor Slough is currently maintained based on a fixed seasonal schedule of pumping at S-332. This schedule was initiated in 1980 under authorization of PL 91-282. The District has submitted a proposal to substitute the current minimum delivery schedule with one based on local rainfall, similar to the Northeast Shark River Slough Rainfall Plan. Beginning in 1983, the U.S. Congress authorized a program of experimental deliveries to ENP (Fascell Bill, PL 98 -181), which allowed the minimum delivery to be temporarily set aside to test alternative water delivery plans for the Park. It is anticipated that modification of the delivery schedule to Taylor Slough will be allowed under the same authorizing legislation. Any related construction activities would require a separate permit and review process. However, the District intends to integrate the Taylor Slough Rainfall plan as part of the C-111 Interim Plan following approval of regulatory agencies.

Based on analysis submitted with the rainfall plan, the current pumping capacity at S-332 (presently limited to 165 cfs) would be increased approximately 100 cfs to provide greater wet season flows to Taylor Slough. The additional amount was based on comparisons of historical records of rainfall and runoff for gauges in the Taylor Slough region. ENP personnel have informally reviewed the rainfall delivery concept and concur a rainfall based schedule better approximates the historical conditions of water delivery, but feel the rain based supplement is too low. Quantity differences were attributed to the period of record selected for the analysis.

The District proposes to implement the Taylor Slough Rainfall plan for normal water deliveries under one of the following options:

1) Implement rainfall plan during the 1991 rainy season with no adjustments to the pumping capacity of S-332. For test purposes, the scheduled delivery plan for S-332 would be replaced with a rainfall schedule that allows pumping up to the existing capacity of the structure (maximum of 165 cfs).

2) Implement rainfall plan during the 1991 rainy season with an additional pumping capacity above the current structure capability, the amount of increase will be determined through cooperative efforts with the ENP staff. Estimates of the amount of additional pumping capacity that could be added to S-332 range between 100 - 335 cfs. The latter amount added to the current capacity (165 cfs) would equal the exsiting conveyance capacity of the L-31W canal (approximately 500 cfs). The District does not propose any increase in the conveyance capacity of the L-31W canal under the Interim C-111 Plan. Similar pumping increases and other canal modifications are currently being evaluated under the COE C-111 GDM.

Selection of the above options will be guided by the permit process, the resulting environmental assessments and necessary construction schedules to implement these changes. In the event that environmental assessments suggest a negative impact will result with implementation of the above options, the District, in consultation with the Interagency Review Committee, may elect to develop an alternate schedule for water delivery to Taylor Slough.

## 5.0 MONITORING STRATEGY

### 5.1. Hydrology and Discharge Monitoring

Implementation of the interim plan will affect three primary areas of interest 1) increase marsh hydroperiod in portions of Northeast Shark River Slough northwest of the new L-31N structure (G-211), 2) reduce the duration and cumulative volume of storm discharges at S-197, and 3) increase routine flows to the ENP Eastern Panhandle and downstream estuaries.

During the first two years of operation under the interim plan, monitoring efforts will focus on quantifying changes in the supply and distribution of water due to modifications in C-111 and L-31N (G-211) canal structures and/or operations. The District proposes to expand and/or integrate collection of hydrologic and hydraulic data collected within the study area. Six different areas of interest will be monitored to evaluate changes in baseline hydrology resulting from the implementation of the interim plan. These include 1) changes in hydrology of Northeast Shark River Slough by addition of G-211, 2) G-211 affects on Bird Drive Basin, 3) monitoring of C-1W discharges, 4) changes in C-111 marsh hydrology, 5) monitoring S-197 discharges, and 6) monitoring flows to the ENP Eastern Panhandle.

### 5.1.1. G-211 Monitoring Northeast Shark River Slough (NESRS)

An experimental water delivery plan for Northeast Shark River Slough (Shark River Slough Rainfall Plan) was implemented in July 1985 and extended to January 1, 1992. In conjunction with this program, an extensive monitoring network was initiated through cooperative efforts of the USGS, ENP and the District. Monitoring of selected sites will be continued to determine how surface and ground water gradients are influenced by operation of G-211. Figure 4 identifies the approximate locations of recording sites and Table 4 describes the information type that will be recorded at each location.

TABLE 4. Hydrologic Monitoring Sites near G-211 in NESRS area. All stations are equipped with continuous recorders. Station locations are shown in Figure 4.

| Station | Data Recording Type |
| --- | --- |
| NP-201 | Rainfall Station and Water Level Recorder |
| NP-202 | Rainfall Station and Water Level Recorder |
| NP-203 | Rainfall Station |
| L-67XW | Canal stage L-67 Ext |
| L-67XE | Surface Water |
| L-67XM | Canal stage L-67 Ext |
| L-67XS | Canal stage L-67 Ext |
| P-33 | Surface Water |
| S-333 | Discharge (cfs), canal stage L-29 |
| NESRS-1 | Surface Water |
| NESRS-2 | Surface Water |
| NESRS-3 | Surface Water |
| NESRS-4 | Surface Water |
| NESRS-5 | Surface Water |
| G-618 | Groundwater Stage |
| G-1502 | Groundwater Stage |
| G-3272 | Groundwater Stage |
| G-3273 | Groundwater Stage |
| G-596 | Groundwater Stage |
| G-1487 | Groundwater Stage |
| Angel's | Groundwater Stage |

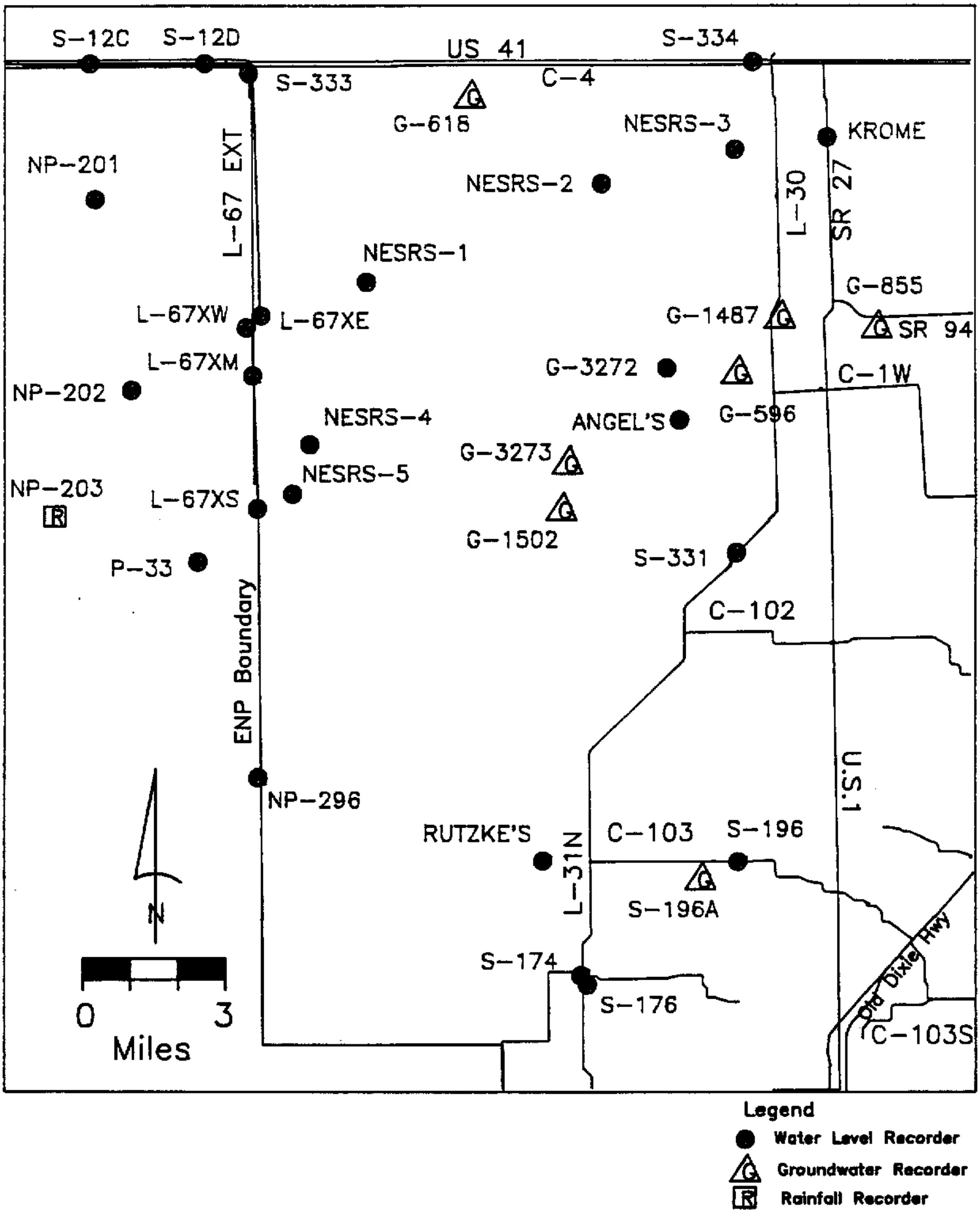



Figure 4. Surface stage and groundwater monitoring sites in the Northeast Shark River Slough area.

### 5.1.2. G-211 Monitoring Bird Drive Basin

Two continuous surface water recording sites will be monitored within the Bird Drive Basin (Figure 4), one located approximately 1.0 mile south of Tamiami Trail on Krome Ave (site Krome) and the second 1.0 mile west of Krome Ave on Kendal Drive (site G-855). Comparisons will be made between hydrographs recorded before and after construction of G-211. Other wells and monitoring sites utilized for the West Dade Wellfield analysis may be included as part of the G-211 monitoring effort.

### 5.1.3. C-1W Monitoring of Seepage Discharges

Previous studies by the District indicated that a significant portion of the wet season flow through S-331 was attributed to seepage from NESRS entering the L-31N canal north of C-1W. This high seepage loss resulted from efforts to provide flood protection to residents west of L-31N and operational changes associated with the test of the Shark River Slough Rainfall Plan. These inflows, in turn, contributed to increased flows to C-111.

Construction of G-211 will provide more flexibility in water control, allowing water levels to be increased to 5.5-6.0 ft NGVD upstream of the structure and significantly reduce seepage into the L-31N canal. Under the operational criteria outlined in Sec. 4.2.2, a portion of the seepage may be diverted through S-338 and discharged through C-1W. Discharges will be monitored throughout the C-1 basin (Figure 3) to determine relative increases, if any, in the flows discharged to Biscayne Bay. Past operational experience has shown, that under light to moderate rainfall conditions, most of the discharges through the S-338 are lost to ground water recharge prior to reaching the S-148 structure. Table 5 describes the flood control stage and discharge characteristics for the C-1 basin structures. Gate openings and stage conditions will be used to compute discharge rates and daily discharge volumes passing through each structure.

### 5.1.4 C-111 Marsh Hydrology

Beginning in 1984, the District and USGS established a network of surface and ground water monitoring sites within the fresh water marshes adjacent to the C-111 canal. This network consisted of five surface water recording gauges (EVER1, EVER2A, EVER2B, EVER3 and EVER4) and two ground water stations (G-3354 and G-1251; Figure 5). Data collected for the period between 1984-1989 will be used to establish baseline conditions prior to implementation of the C-111 Interim Plan. Hydrologic monitoring will be resumed and continue throughout the permit duration at these same locations. Pre and post conditions will be compared to determine basin changes in surface water depths, duration of flooding and interactions of surface and ground water. As part of an existing contract with ENP and Florida International University, a water budget will additionally be developed that estimates the amount of seepage contributed to this region by C-111 during various stage conditions.

TABLE 5. Optimal Stages, Discharge Characteristics and Storm Operating Criteria for C-1 Basin Canals During Design Storm.

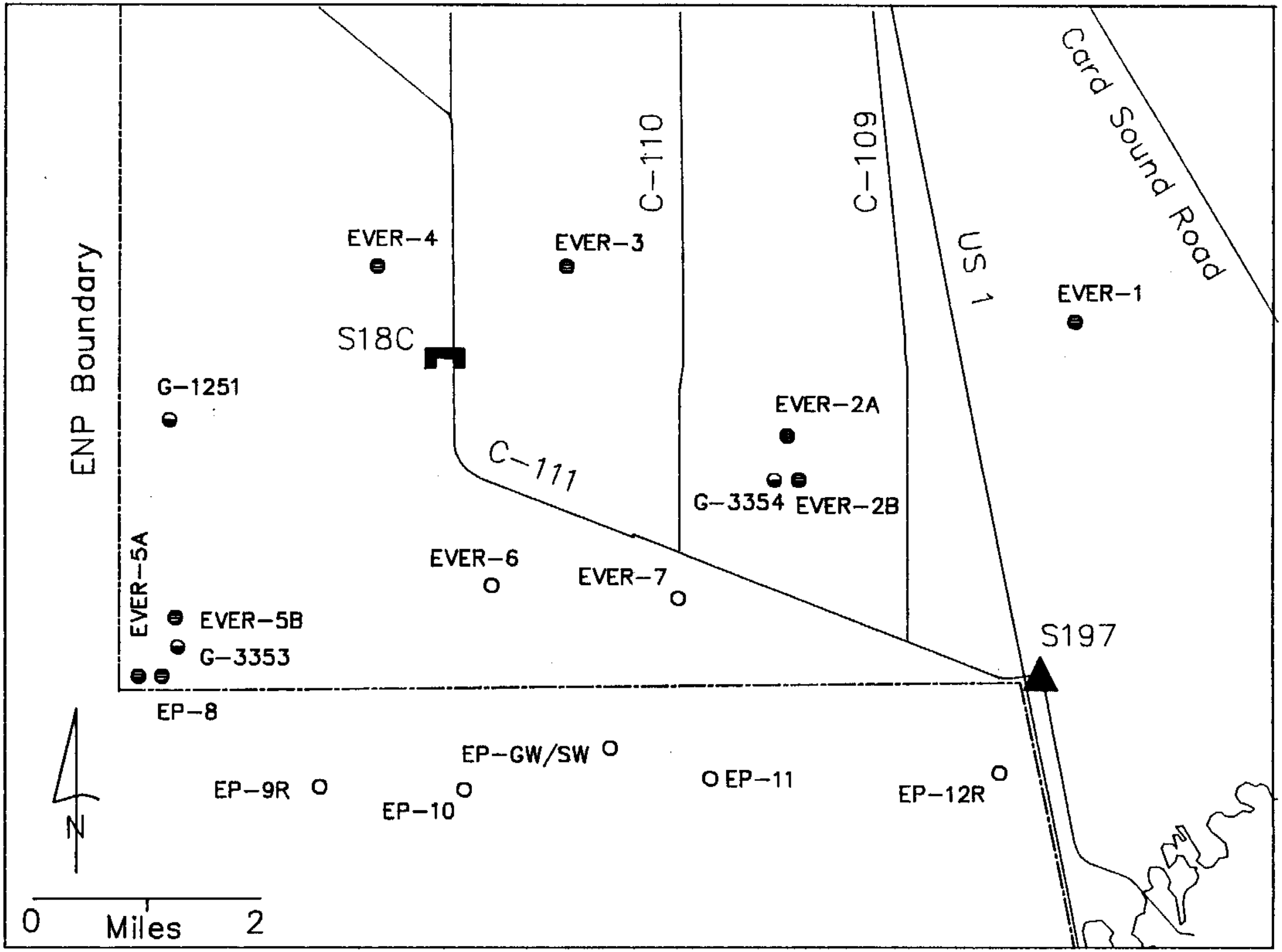
| Canal Reach | Control Structure | Flood Control Stage NGVD @ | Design Discharge # |
|---|---|---|---|
| L-31N to S-338 | S-338 | 5.5-6.0 + | 305 cfs |
| S-338 to S-148 | S-148 | 5.2 | 1500 cfs |
| S-148,149,122 to S-21 | S-21 | 2.4 * | 2560 cfs |
| C-1N Canal | S-149 | 6.2 | 400 cfs |

@ Flood control stage is the maximum stage allowed in the canal before mandatory flood control releases are triggered.

# Rate of discharge for a specific structure during a standard project storm as defined by U.S. Army Corps of Engineers.

\+ Proposed canal stage after construction of G-211. During storm events, operating conditions will follow procedures as described in Sec. 4.1.2. Canal stages during routine conditions will be controlled by discharging excess water according to the priority described in Sec. 4.2.2.

* Canal stage during the dry season will be maintained at a 1.2 ft NGVD for water supply deliveries.




o Stage and Salinity Recorder
● Groundwater Stage Recorder
GW/SW Ground and Surfacewater Stage Recorder
● Surfacewater Stage Recorder

Figure 5. Surface stage and groundwater monitoring sites in the lower C-111/ENP Panhandle area.

5.1.5. S-197 Discharge Monitoring

Although the occurrence of plug removal at S-197 has been infrequent, significant damage to the marine habitat in Manatee Bay has been documented due to low salinities created by these large discharge events. The proposed modifications and change in operation strategy is expected to reduce the extent of similar storm related impacts on Manatee Bay/Barnes Sound by reducing the duration of discharge events. Since no additional drainage capacity has been provided under the interim plan, the frequency of similar events requiring full operation of S-197 culverts (13 culverts open) will remain low. All discharge events, however, will be reported and include records of gate operation, length of time culverts remain open and computed discharge volumes. Discharge rating curves for the new structure will be developed for various number of culvert openings and stage conditions.

Quick access to stage information will be critical for effective operation of control structures. The District currently has automatic stage recording devices at several critical locations (S-176, S-177, and S-18C). Headwater and tailwater stages are continuously recorded and transmitted directly to the District Operations Room in West Palm Beach and the Homestead Field Station by telemetry or through radio-phone connections. Expansion of this remote network has been planned to include S-331, S-332, S-334, S-338, S-197 and G-211 (Figure 6).

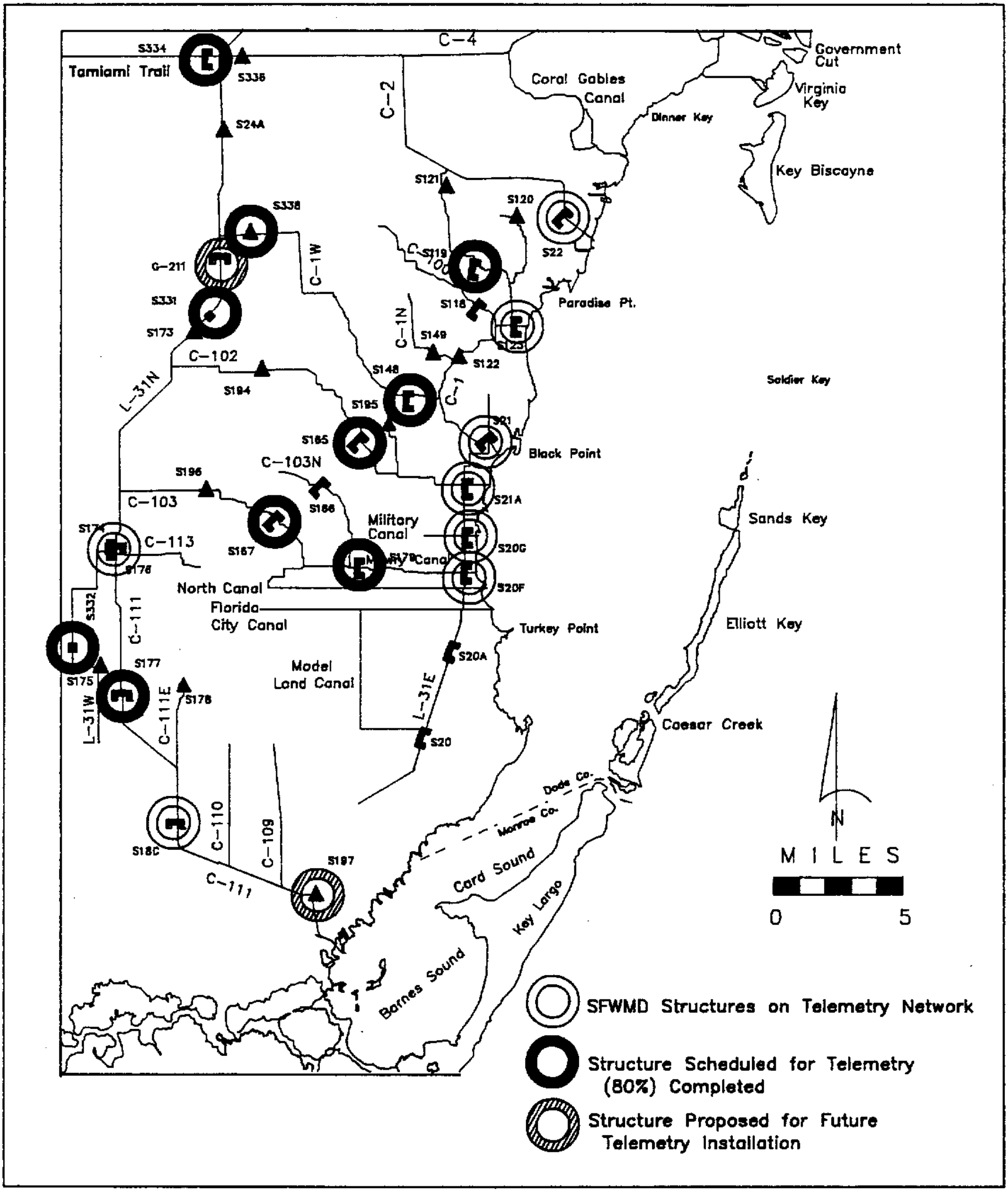



Figure 6. Existing and proposed water control structures monitored by remote telemetry.

### 5.1.6. Monitoring Flows to Eastern Panhandle from C-111 Gaps

Water supply to ENP Eastern Panhandle flows through a series of 55 gaps spaced along the south levee of the C-111 canal between S-18C and S-197. Natural ground elevations at these gap openings range from 0.6 to 1.6 ft NGVD. Cutout widths of the gaps also vary (attachment 4). Recent studies suggest water flowing from the gaps may be confined to the marsh along the canal due to prevailing southeast gradients in land topography and the influence of the US-1 borrow canal. Additional studies by ENP indicate the C-111 canal has altered surface sheet flow and ground water movement to downstream estuaries in Joe Bay and Long Sound causing hypersaline conditions to periodically develop. The current plan would modify the cutout openings in the most western gaps to promote increased flow to the western areas of the ENP Eastern Panhandle and achieve better distribution of flows.

Prior to any improvements of the gaps, the District will complete topographic surveys and analysis of existing hydrologic conditions. A study has been contracted with ENP and Florida International University to develop a detailed water budget for the ENP Eastern Panhandle region and quantify present distributions of flow through the C-111 gaps (attachment 4). Monitoring of baseline conditions will continue through the first two years (November 1989 - December 1992) within the permit time frame (ending November 1994). This information will be presented to the Interagency Review Committee for their recommendations concerning the locations, number of gaps, and type of modifications. Additional monitoring will be conducted after gaps have been modified to compare changes in the distribution of water flow.

Monitoring of baseline hydrology will consist of two phases, first quantifying the amount of flow and spatial distribution through the gaps at selected locations and second, evaluating responses of downstream stages in the fresh water marsh to these inflows. Flows through the cutouts in the C-111 levee will be measured under varying canal stages to develop rating curves equating discharge volume with water levels. A network of surface and ground water stage recorders has been previously installed inside the ENP boundary (Figure 5). Two additional surface water stage recorders (EVER-6 and EVER-7) will be installed midway between the park boundary and the C-111 canal. Surface water profiles from this network will then be compared with discharge amounts flowing through various gaps. Conductivity recorders will also be installed at selected gauge sites to evaluate spatial movement and seasonal trends in the fresh/salt water interface within the lower marsh.

Due to the experimental nature of the gap modifications, all modifications will be interim until an optimum cutout configuration can be ascertained based on field responses and operation experience. Fine tuning of the cutouts may be required after initial modifications are made. Consequently, any material removed to widen gaps will be retained on site and stored on existing spoil piles. Off-site disposal of spoil material will be evaluated after optimum cutout configurations have been established.

## 6.0. ENVIRONMENTAL MONITORING

Various environmental studies are currently being conducted or have recently been completed in the C-111 Basin by the District, ENP, and Dade County Environmental Resource Management (Table 6). Several of these studies were initiated to provide baseline data relating the ecology of the area with local and regional hydrology. On-going studies are expected to be completed prior to any improvements in the existing C-111 gaps. A concurrent review of these reports or studies should be conducted by the Interagency Review Committee prior to any expansion or implementation of new environmental studies. This action will help to reduce duplication of previous study efforts and identify the more relevant biotic and abiotic parameters that respond to variations in fresh water inflow and/or salinity gradients.

Table 6. Environmental Studies Conducted in the C-111 Study Area (see attachments 6 - 10).

| Agency | Type of Study | Study Period Ends |
|---|---|---|
| SFWMD/ENP | Wading Bird Use Roseate Spoonbill | Mid 1991 |
| SFWMD/ENP | Benthic Productivity ENP Eastern Panhandle | Oct 1989 |
| SFWMD | Vegetation, Water Quality, Hydrology, Estuarine Salinity & Productivity | Oct 1985 - Dec 1987 |
| SFWMD | Freshwater Flow & Mangrove Habitat Use by Fish | Nov 1988 - Nov 1990 |
| DERM | SWIM Studies Biscayne Bay Biological & Water Quality (Manatee Bay/Barnes Sound) | Oct 1989 - On-going |

Until the above studies and reviews are complete, environmental monitoring will be limited to four immediate areas of concern (1) determining Manatee Bay/Barnes Sound salinity responses to storm related discharges at S-197, (2) salinity gradients in Northeast Florida Bay associated with normal flow diversions through the C-111 gaps, (3) monitoring any additional influx of nutrients in the ENP Eastern Panhandle resulting from routine flows through the gaps, and (4) monitoring salinity and water quality impacts downstream of S-21 (C-1W diversions).

### 6.1 Storm Discharge and Salinity Monitoring in Manatee Bay

Storm events that require opening of at least three culverts will be monitored to establish the spatial impacts on salinity gradients and to determine how quickly antecedent salinity gradients are re-established following a discharge event. Changes in salinity, dissolved oxygen, pH, and temperature will be monitored in both Manatee Bay and Barnes Sound. A network of open water monitoring stations established by Haunert (1989, unpublished; attachment 8) during previous environmental studies will be used. This network consists of 15 open water stations, twelve located within Manatee Bay and three in Barnes Sound (Figure 7). A complete set of data will be collected as soon as possible after each discharge event begins, repeated after the structure is closed, and again at one and three weeks following the termination of each discharge event. Measurements at each open water station will be obtained from surface to bottom at 0.5 m increments. Anecdotal observations concerning impacts on benthic habitats will be recorded during each sampling trip.

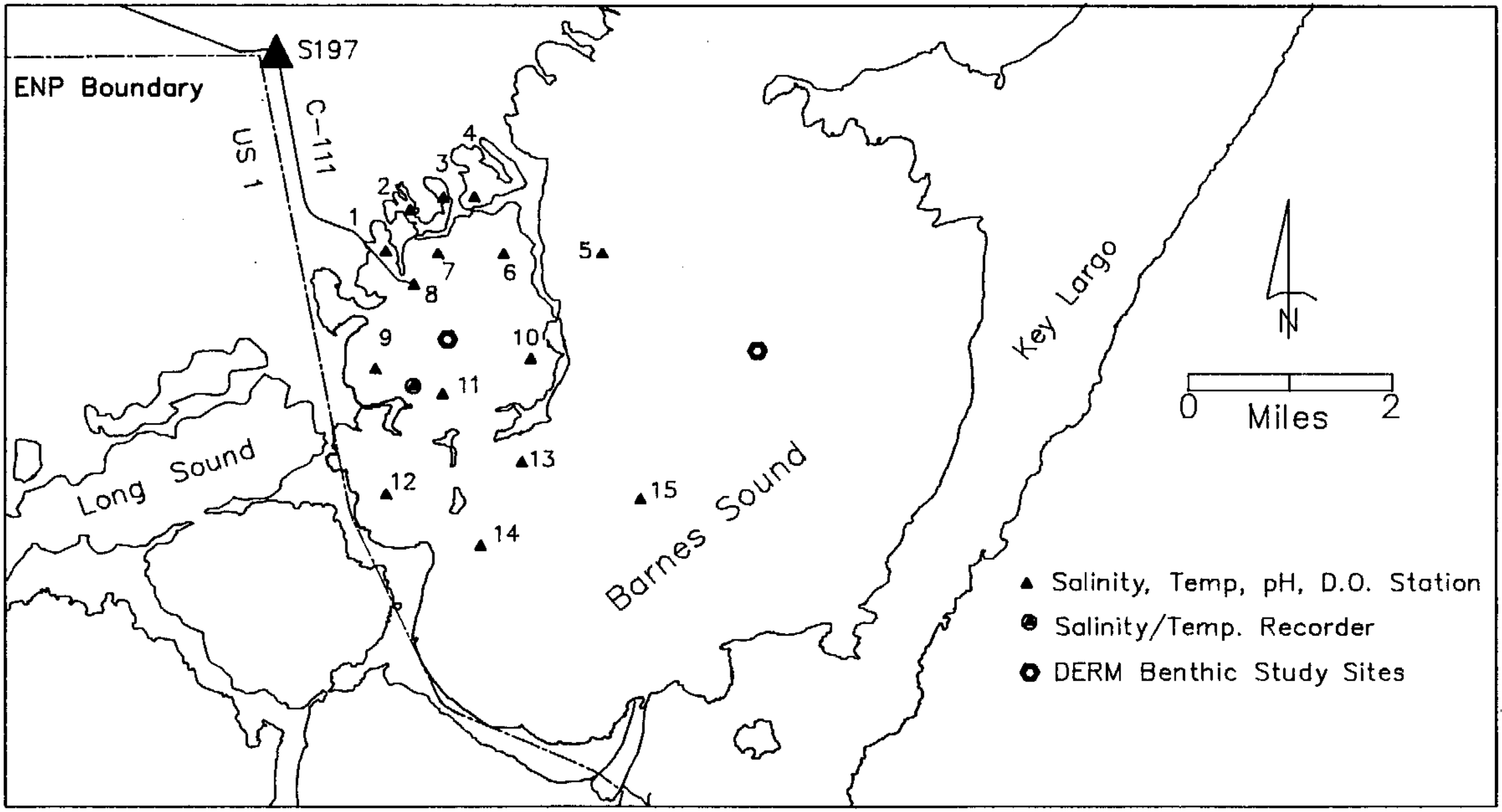


Figure 7. Monitoring Stations in Manatee Bay and Barnes Sound

Salinity monitoring will additionally be augmented by a continuous recorder located just off the southwest shoreline approximately 1.0 mile downstream of the C-111 canal outfall (Figure 7). Measurements recorded at this station will be correlated with open water observations during and after major storm events to estimate temporal and spatial changes in salinity gradients.

Other environmental data collected in a cooperative study with DERM will provide further documentation of discharge events (see attachment 10). DERM currently maintains an independent sampling program to monitor trends in the epifloral and epifaunal abundance in Manatee Bay and Barnes Sound (Figure 7). Measurements and observations are obtained quarterly. Data and observations obtained during the quarterly sampling preceding and after each storm event will be compared to measure the relative impacts of the discharge event.

## 6.2 Salinity Gradients in the ENP Eastern Panhandle

The spatial and temporal interactions between fresh water inflows and downstream salinity gradients occurring in the ENP Eastern Panhandle study area are not well known. Previous studies by Tabb et al (1967) and the District (Swift 1988, unpublished; attachment 8) indicate landward movement of saline waters into the marsh varies directly with fresh water inflows. A recent study by Montague et al (1989; attachment 7) also indicates tidal creeks in the region vary in salinity with higher salinities occurring east to west and increase from upstream toward the open bay. Modifications in the C-111 cutouts will be designed to alter the distribution and discharge volume passing through the western gaps to create more equitable distribution of fresh water and salinity gradients.

Salinity in the ENP Eastern Panhandle and downstream estuaries in Florida Bay will be monitored through a network of continuous recording stations previously established by ENP (Figure 8). Table 7 describes the type of information recorded at each station location. Six recording sites will be modified to include instrumentation for recording surface water conductivity (salinity). This information will assist in interpreting movement and flow direction of surface water discharged through the C-111 gaps and seasonal trends in the landward movement of the salt front.

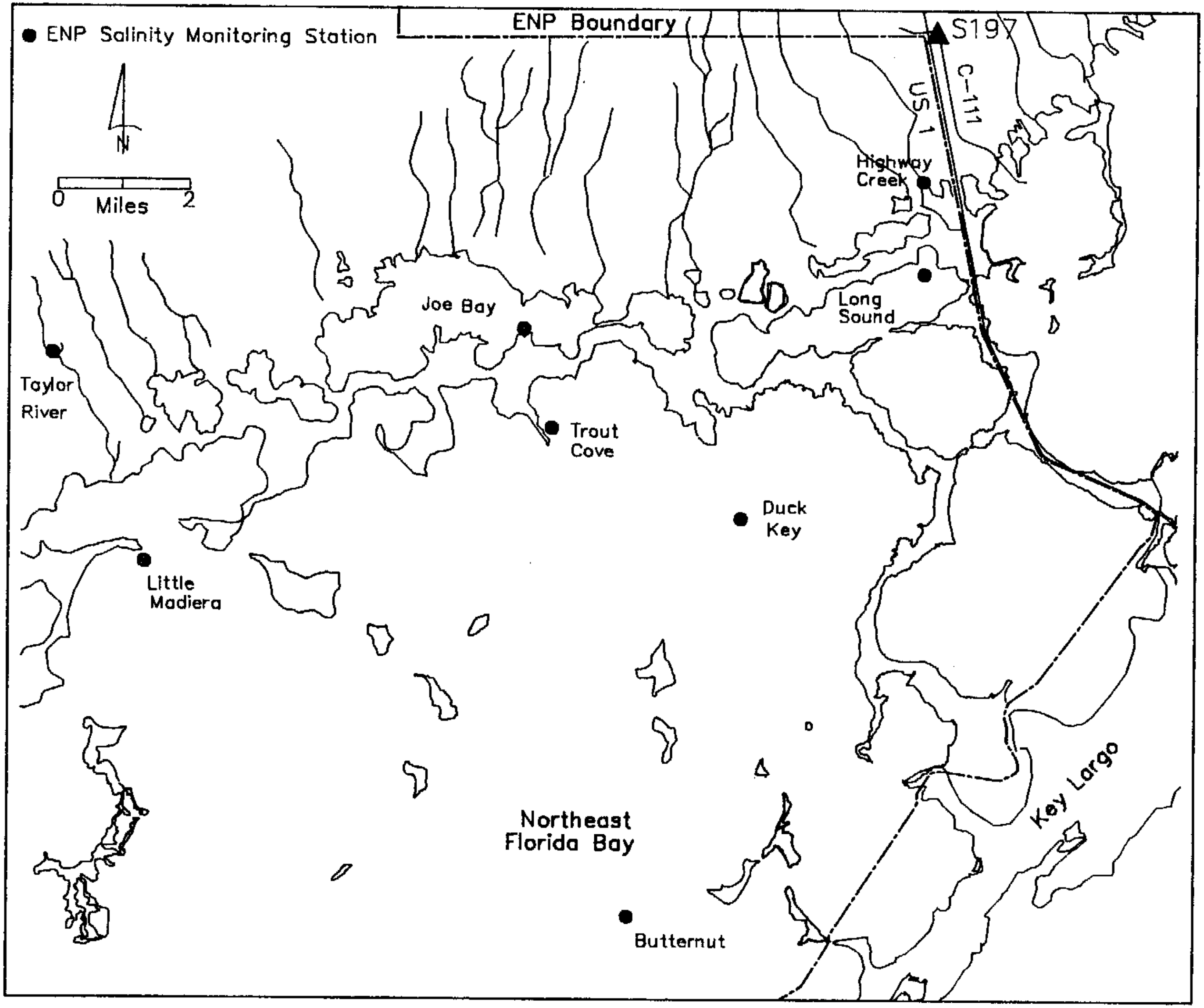



Figure 8. Salinity Monitoring Stations NE Florida Bay

Table 7. Salinity Stations in ENP Eastern Panhandle and NE Florida Bay. Parameters are recorded continuously. Sites with EP-prefix are shown in figure 5.

| Station Name | Data Type Recorded |
|---|---|
| Joe Bay | Temperature/Salinity |
| Trout Cove | Temperature/Salinity |
| Long Sound | Temperature/Salinity |
| Highway Creek | Temperature/Salinity |
| Duck Key | Temperature/Salinity |
| Little Madiera | Temperature/Salinity |
| Taylor River | Temperature/Salinity |
| Butternut | Temperature/Salinity |
| EP-9R | Surface Stage/Salinity* |
| EP-10R | Surface Stage/Salinity* |
| EP-11R | Surface Stage/Salinity* |
| EP-12R | Surface Stage/Salinity* |
| EP-GW/SW | Surface Stage/Salinity* |
| EP-9R | Surface Stage/Salinity* |

* Stations will be modified to include salinity.

Empirical relationships will be developed between inflow volume, water level and downstream salinities to compare corresponding differences among these parameters and resulting gradients in northeast Florida Bay before and after the cutout modifications. Evaluations will include wet and dry season comparisons of the amount of variation in downstream salinity that can be explained by seasonal differences in inflows and/or stage conditions.

## 6.3 Water Quality Monitoring

The District currently maintains a water quality monitoring network in the lower C-111 basin (Figure 9). Some of the canals and structures affected by the interim plan modifications are included in the routine sampling of nutrients and other constituents (Table 8). Results of these analyses will be included in the reporting schedule for the monitoring plan. The District will expand existing cooperative agreements or conduct other specific monitoring for the ENP Eastern Panhandle and portions of Biscayne Bay and Manatee Bay that may be affected by the interim plan.

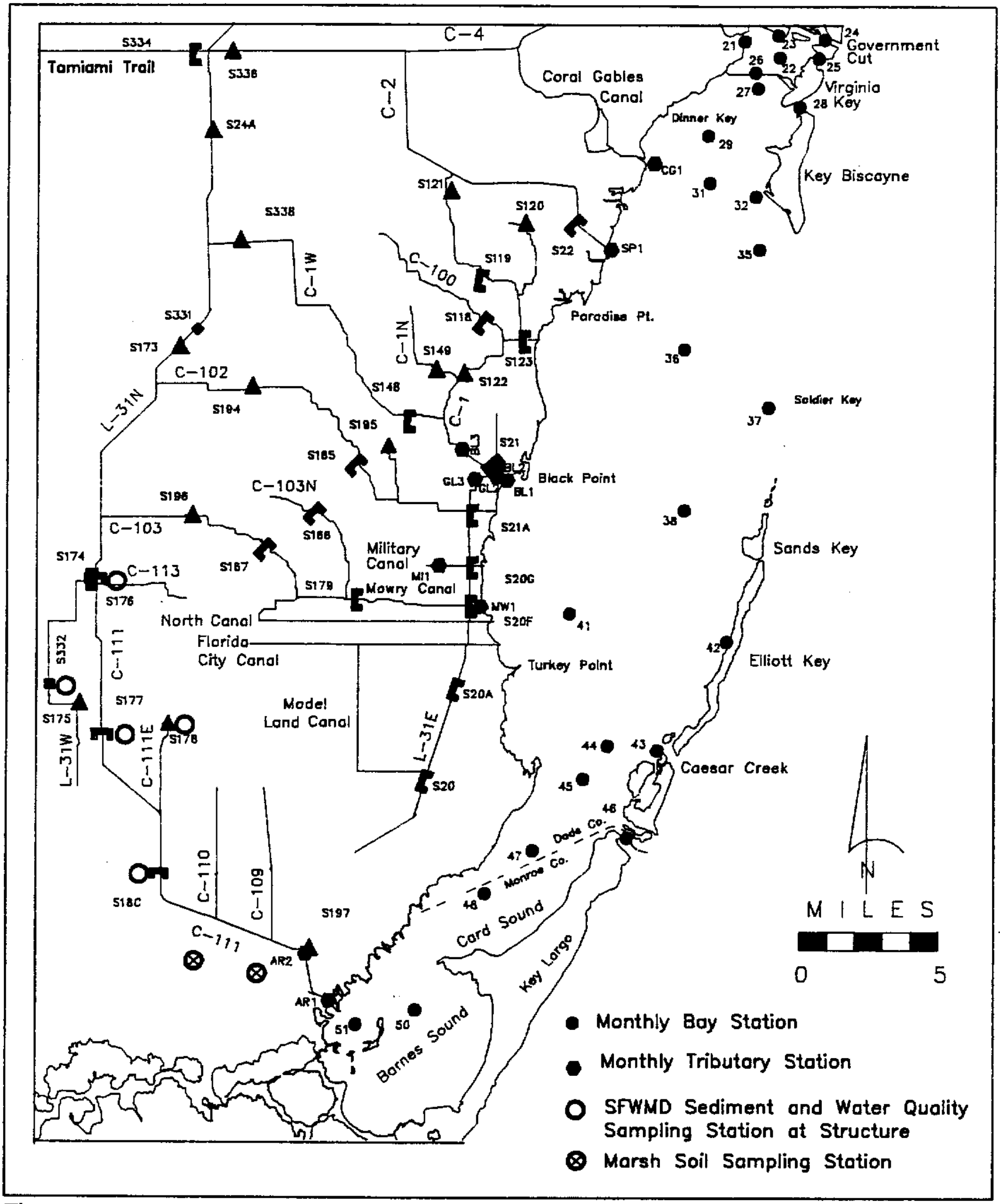



Figure 9. Water quality stations routinely monitored throughout the C-111 and Biscayne Bay area by DERM and the District.

### 6.3.1 ENP Eastern Panhandle Water Quality - Nutrients and Pesticides

Studies by Montague et al (1989), Haunert (1988, unpublished) and Swift (1988, unpublished) all suggest surface waters in the ENP Eastern Panhandle and nearshore bay areas contain extremely low concentrations of nutrients (nitrogen and phosphorous). Any nutrients entering the ENP Eastern Panhandle through discharges from the canal cutouts are quickly removed from the surface waters by marsh vegetation and soils. However, unless carefully monitored, additional diversion of water to the panhandle could potentially exceed the assimilative capacity of these marsh communities to absorb excess nutrients.

In addition to the routine sampling conducted at the various C-111 structures, marsh water quality will be monitored along portions of four transects previously established by Swift (1988, unpublished, see attachment 8). Monthly surface water samples will be collected and analyzed from stations located immediately adjacent to the cutouts and from sites approximately 0.5 miles downstream (Figure 9). Analysis of previous results showed nutrient concentrations were frequently found at or near detection limits and were far lower in concentration than internal canal samples. In the event that changes in these threshold conditions occur, the sampling program will be modified to include additional sampling at fixed intervals downstream of the cutouts.

Portions of the C-111 canal are also routinely monitored by the District for presence of pesticides and heavy metals in water and sediments (Figure 9 and Table 8). During the March 21 Interagency Meeting, Dade County DERM requested the District pesticide monitoring be expanded to include additional compounds as listed in Appendix 2 (see Interagency Meeting Comments). These compounds will be included in the sample analysis for S-18C collections.

Sediment samples will be collected twice annually during the wet and dry seasons upstream of the structure locations in Figure 9. Results will be compared with previous monitoring data to identify any trends in accumulations of materials resulting from increased diversion of water to the Panhandle. In the event increases are detected above previous background levels, additional samples will be collected at the marsh water quality locations downstream of the C-111 gaps (Figure 9). Soils analysis will include aluminum concentrations, amount of percent silt/clay, Cu, Zn, Fe, Cd, Hg, Pb, As, and amount total organic carbon (TOC) contained in each sample.

### 6.3.2 Water Quality Monitoring Adjacent S-21 in Biscayne Bay

Under an existing SWIM contract with DERM, water quality samples are collected at several locations in Manatee Bay, Barnes Sound and Biscayne Bay (Figure 9). Table 8 describes the range of parameters and frequency of collection at each site. Key stations from this sampling network (36, 37, 38, 41, 50 and 51) will be used to monitor changes in baseline conditions before and after implementation of the C-111 Interim Plan. Additional arrangements with DERM will be made to establish monitoring stations immediately downstream of S-21 in Biscayne Bay and sampled during periods when S-338 is discharging (events requiring diversion of seepage from L-31 or storm discharges). Three additional stations will be located at 0.5, 1.0 and 1.5 mi intervals along a transect extending from the structure outward into the bay. Costs associated with this additional sampling will not be funded through existing SWIM contracts.

Table 8. Routine Water Quality Analysis for District Structures.

| **Physical Chemical** | **Units** |
|---|---|
| Temperature | C |
| Dissolved Oxygen | mg/L |
| Sp. Conductivity | umhos/cm |
| pH | - |
| Turbidity | NTU |
| Color | - |
| Total Sus. Solids | mg/L |
| **Nutrients** | |
| Nitrate | mg N/L |
| Nitrate | mg N/L |
| Ammonia | mg N/L |
| Inorganic Nitrogen | mg N/L |
| Organic Nitrogen | mg N/L |
| Total Nitrogen | mg N/L |
| Ortho Phosphorus | mg P/L |
| Total Phosphorus | mg P/L |
| **Major Ions** | |
| Alkalinity | $CaCO_3$mg/L |
| Chloride | mg/L |
| Total Iron | mg/L |
| Silica | mg/L |
| Sulfate | mg/L |
| Sodium | mg/L |
| Potassium | mg/L |
| Calcium | mg/L |
| Magnesium | mg/L |
| **Trace Metals** | |
| Total Mercury | microog/L |
| Total Cadmium | microog/L |
| Total Copper | microog/L |
| Total Zinc | microog/L |
| Total Arsenic | microog/L |
| Total Lead | microog/L |

| **Pesticides** | **Active Compound** |
|---|---|
| 2,4-D | Kelthane/Dicofol |
| Dichloroprop | BHC,Gamma/Lindane |
| 2,4,5-T | Malathion |
| Silvex | Methamidophos |
| Alachlor | Methomyl |
| Aldicarb | Methoxychlor |
| Aldrin | Methyl Bromide |
| Ametryne | Methyl Parathion |
| Benomyl | Metribuzin |
| BHC,Alpha | Mebinphos |
| BHC,Beta | Azodrin/ |
| | Monocrotophos |
| BHC,Delta | Oxamyl |
| Bromacil | Paraquat |
| Carbaryl/Sevin | Parathion |
| Carbofuran | PCB 1016 |
| Chlordane | PCB 1221 |
| Chloropicrin | PCB 1232 |
| Chlorothalonil | PCB 1242 |
| Diazinon | PCB 1254 |
| Dieldrin | PCB 1260 |
| Endosulfan,Alpha | Perthane |
| Endosulfan,Beta | Phorate |
| Endosulfan Sulfate | DDD,PP |
| Endrin | DDE,PP |
| Endrin/ | |
| Aldehyde | DDT,PP |
| Ethion | Prometryne |
| Fonofos/ | |
| Dyfonate | Simazine |
| Ethoprop | Toxaphene |
| Glyphosate | Trifluralin |
| Guthion | Trithion/ |
| | Carbophenthion |
| Heptachlor | |
| Expoxide | Zinc Phosphide |
| Heptachlor | |

Table 9. Water Quality Parameters Collected by DERM in Biscayne Bay.

| Parameter | Number of Stations | Frequency | Depth |
|---|---|---|---|
| Ammonia N | 50 | monthly | mid surface |
| Cadmium | 29 | bi-monthly | surface |
| Chlorophyll a | 4 | monthly | surface |
| Color | 74 | monthly | surface |
| Conductance | 74 | monthly | surface |
| Copper | 29 | bi-monthly | surface |
| Depth | 74 | monthly | |
| Dissolved Oxy | 74 | monthly | mid surface |
| Feccal Coli. | 74 | monthly | surface |
| Lead | 29 | bi-monthly | surface |
| Nitrate/Nitrite | 50 | monthly | surface |
| pH | 74 | monthly | surface |
| Pheophytin a | 4 | monthly | mid surface |
| oP04 | 50 | monthly | mid surface |
| P.A.R. | 74 | monthly | s, 3', b |
| Temp. | 74 | monthly | mid surface |
| Total Coli. | 74 | monthly | surface |
| Total Non-filter Residue | 74 | monthly | mid surface |
| Turbidity | 74 | monthly | surface |
| Zinc | 29 | monthly | surface |

## 7.0 C-111 SPREADER CANAL FEASIBILITY STUDY

As part of the U.S. Army Corps of Engineers permit conditions and in conjunction with the U.S. Fish and Wildlife Service, the District has been directed to evaluate the potential of re-establishing overland sheet flow through portions of the wetlands within the C-111 basin. Conceptually, the plan would divert water from C-111 to C-111E by holding a slightly higher headwater stage at S-18C. Water entering C-111E would then be diverted east through an existing east-west drainage ditch and allowed to overflow along the south rim of this distribution canal across the marsh (Figure 10). Improvements to existing canals would be required and along with some additional excavation to manage runoff from private lands.

Environmental benefits and associated permitting requirements of this proposal were discussed at the March 21 Interagency Committee Meeting. Most of the participants felt this proposal would require additional regulatory permits and could potentially involve a lenghty review process. However, there were widely recognized benefits associated with the proposed modifications that would enhance capabilities to manage water and improve environmental conditions.

The District proposes to evaluate the technical feasibility of the above proposal through a three step process according to the following:

1) Compile and map relavent topography data for the affected canals and adjacent wetlands. Depending on the level of detail available, the District may acquire additional topographic data to adequately

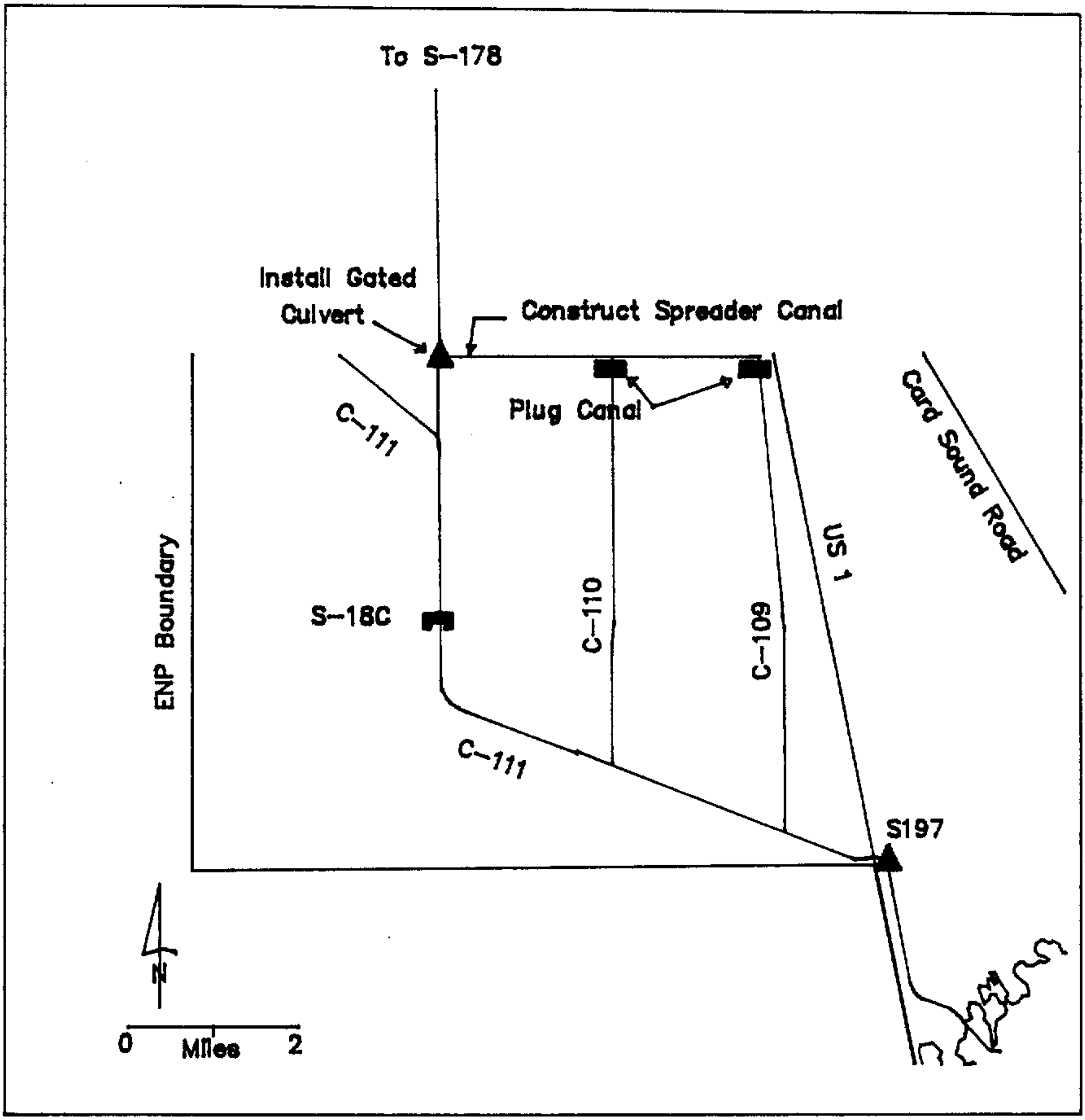



**Figure 10. Generalized diagram of the C-111E spreader canal proposal.**

characterize elevation and slope parameters that will influence movement of water in the region.

2) The District will simulate the required changes in structure operations and canal improvements to divert water by gravity through C-111E and adjacent east-west spreader canal. Simulations will be made of normal water delivery schedules and during flood conditions with and without proposed spreader swale improvements, in conjunction with the Taylor Slough rainfall plan. Changes in flow rates will be described including changes in hydroperiod (duration and frequency) for adjacent lands with and without the proposed improvements. Analysis will also include comparisons of the change in water budget for the Eastern Panhandle of ENP with the proposed project improvements.

3) Identify all private lands affected by proposed modifications or resulting changes in hydroperiod.

Results of the above analyses will be presented to the Interagency Review Committee for discussion and consultation. Assuming that proposed modifications are feasible and would provide some net environmental benefit, the District will implement a demonstration project to further test the proposed improvements, after acquiring the necessary permits.

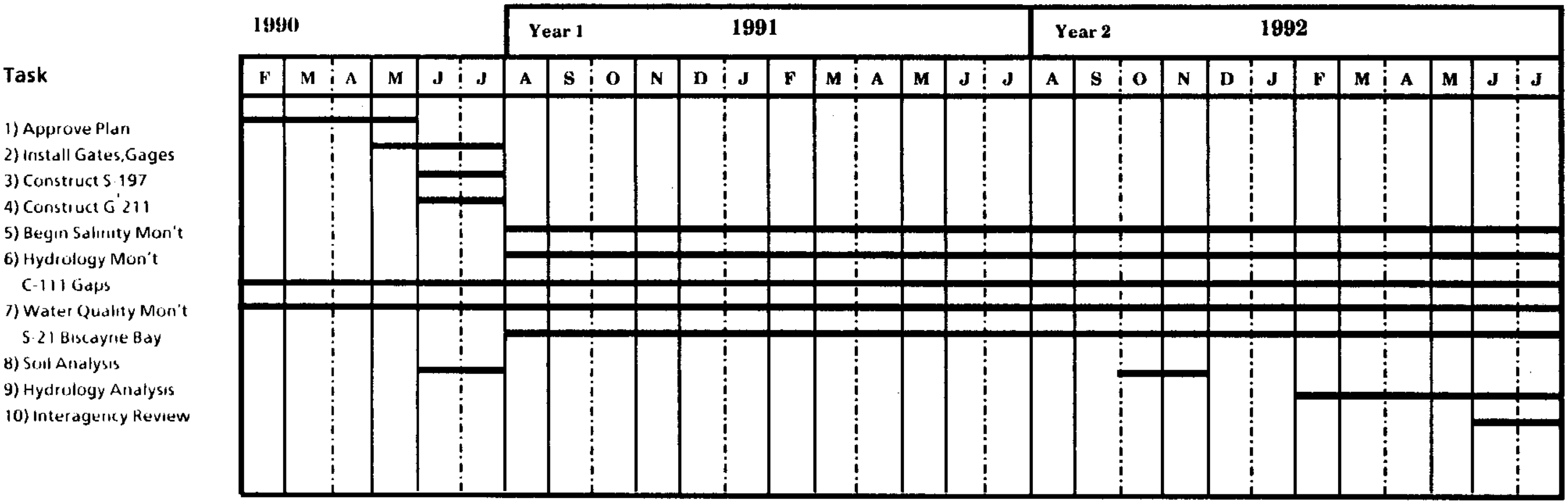
## 8.0 SCHEDULE OF IMPLEMENTATION

Additions and modifications of structures will occur in two phases. Phase I will include construction of S-197 and G-211 structures. Portions of the monitoring plan relating to these structures will be implemented immediately after acceptance of the plan by DER. Operating and monitoring criteria will continue for a two year test period. Phase II will include modifying the C-111 gap openings and continuation or revision of operating and monitoring criteria initiated under Phase I. Figure 11 depicts the conceptual time frame for major components of the monitoring plan.

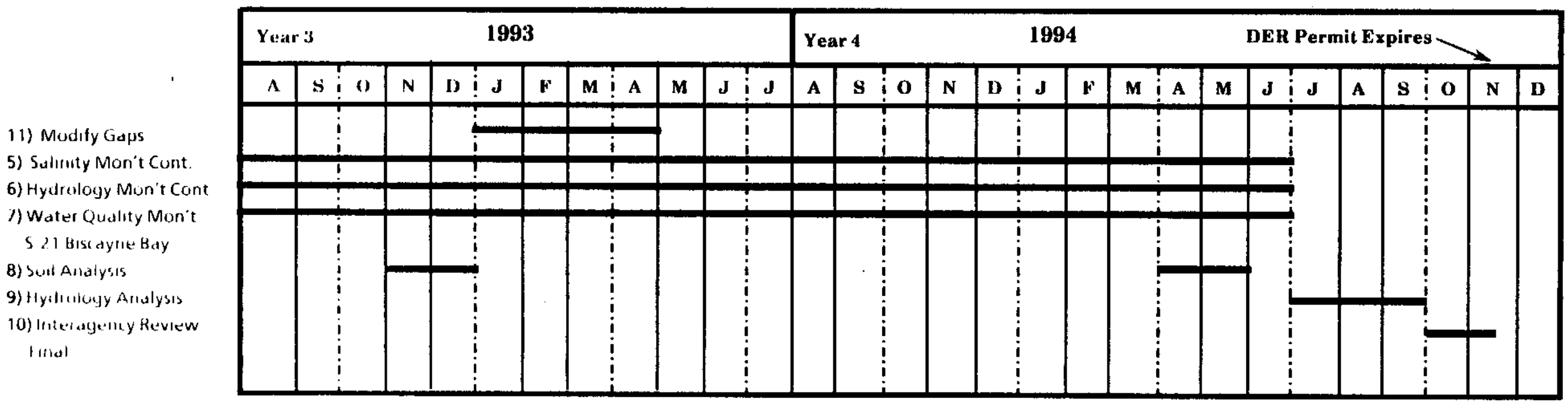
## 9.0 REPORTING

Progress reports will be submitted annually to DER and members of the Interagency Committee. These reports will briefly summarize the data collection effort by the District and any cooperating agencies and present summaries of raw data collected in conjunction with the operational logs for various structures. Detailed reports concerning hydrologic analysis, associated water quality analysis and available biological data will be presented after completion of the Phase I test program (August 1993) and at the conclusion of the permit period (November 1994). Results of the analyses for C-111E spreader canal diversion proposal will be made available at the conclusion of the two year test (Phase I).

## PHASE 1 : Initial Two Year Test




## PHASE 2 : Operation After Gaps Modified



Appendix 1. U.S. Corps of Engineers/U.S. Fish and Wildlife Permit Special Conditions

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 4970
JACKSONVILLE, FLORIDA 32232-0019

REPLY TO
ATTENTION OF

PBN
1. O
2. ESD

Regulatory Division
South Permits Branch
89IPC-20492

MAR. 1 2 1990

Mr. Ronald Bearzotti
Project Administrator
Construction Management Department
South Florida Water Management Department
P.O. Box 24680
West Palm Beach, Florida 33416-4680

Dear Mr. Bearzotti:

We are pleased to enclose the Department of the Army permit and a Notice of Authorization which should be displayed at the construction site. Work may begin immediately but the appropriate Regulatory Section Chief as representative of the District Engineer must he notified of:

a. The date of commencement of the work.

b. The dates of work suspensions and resumptions if work is suspended over a week, and

c. The date of final completion.

Regulatory Section Chiefs addresses and telephone numbers are shown on the enclosed map. The Section Chief is responsible for inspections to determine that permit conditions are strictly adhered to. A copy of the permit and drawings must de available at the site of work.

IT IS NOT LAWFUL TO DEVIATE FROM THE APPROVED PLANS ENCLOSED.

Sincerely,

John F. Adams
Chief, Regulatory Division

Enclosures

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**This notice of authorization must be conspicuously displayed at the site of work.**

United States Army Corps of Engineers

MAR. 1 2 1990
19______

A permit to MAKE STRUCTURAL CHANGES OT THE EXISTING C-111 FLOOD CONTROL SYSTEM.

at SECTIONS 3,10,&11, TOWNSHIP 59 S, RANGE 38 E; & L-31 NORTH CANAL, SECTION 11, TOWNSHIP 55 S, RANGE 39 E, DADE COUNTY, FLOIDA.

has been issued to SOUTH FLORIDA WATER MANAGEMENT DISTRICT c/o MR. RONALD BEARZOTTI on MAR. 1 2 1990 19

Address of Permittee P.O. BOX 24680 WEST PALM BEACH, FLORIDA 33416-4680

Permit Number

89IPC-20492

BRUCE A. MALSON, COL CE

District Commander

ENG FORM 4336, Jul 81 (33 CFR 320-330) EDITION OF JUL 70 MAY BE USED

(Proponent: CECW-O)

DEPARTMENT OF THE ARMY PERMIT

Permittee: SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Permit Number: 89IPC-20492

Issuing Office: U.S. Army Engineer District, Jacksonville

NOTE: The term "you" and its derivatives, as used in this permit, means the permittee or any future transferee. The term "this office" refers to the appropriate district or division office of the Corps of Engineers having jurisdiction over the permitted activity or the appropriate official of that office acting under the authority of the commanding officer.

You are authorized to perform work in accordance with the terms and conditions specified below.

Project Description: The project is make structural changes to the existing C-111 flood control system.

The work described above is shown on the attached plans numbered 89IPC-20492 in 8 sheets; dated May 25, 1989.

Project Location: Canal 111 (C-111), Sections 3, 10, and 11, Township 59 South, Range 38 East; and L-31 North Canal, Section 11, Township 55 South, Range 39 East, Dade County, Florida.

Permit Conditions:

General Conditions:

1. The time limit for completing the work authorized ends on MAR 12 95. If you find that you need more time to complete the authorized activity, submit your request for a time extension to this office for consideration at least one month before the above date is reached.

2. You must maintain the activity authorized by this permit in good condition and in conformance with the terms and conditions of this permit. You are not relieved of this requirement if you abandon the permitted activity, although you may make a good faith transfer to a third party in compliance with General Condition 4 below. Should you wish to cease to maintain the authorized activity or should you desire to abandon it without a good faith transfer, you must obtain a modification of this permit from this office, which may require restoration of the area.

3. If you discover any previously unknown historic or archeological remains while accomplishing the activity authorized by this permit, you must immediately notify this office of what you have found. We will initiate the Federal and state coordination required to determine if the remains warrant a recovery effort or if the site is eligible for listing in the National Register of Historic Places.



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4. If you sell the property associated with this permit, you must obtain the signature of the new owner in the space provided and forward a copy of the permit to this office to validate the transfer of this authorization.

5. If a conditioned water certification has been issued for your project, you must comply with the conditions specified in the certification as special conditions to this permit. For your convenience, a copy of the certification is attached if it contains such conditions.

6. You must allow representatives from this office to inspect the authorized activity at any time deemed necessary to ensure that it is being or has been accomplished in accordance with the terms and conditions of your permit.

Special Conditions:

1. The permittee agrees to do a detailed feasibility analysis of the Fish and Wildlife Service's culvert/swale proposal to demonstrate the potential for inducing sheetflow through the eastern wetland, using the routine flows currently passing through S-18C as the source of water. (PI)

Further Information:

1. Congressional Authorities: You have been authorized to undertake the activity described above pursuant to:

( ) Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403).

(X) Section 404 of the Clean Water Act (33 U.S.C. 1344).

( ) Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. 1413).

2. Limits of this authorization.

a. This permit does not obviate the need to obtain other Federal, state, or local authorizations required by law.

b. This permit does not grant any property rights or exclusive privileges.

c. This permit does not authorize any injury to the property or rights of others.

d. This permit does not authorize interference with any existing or proposed Federal projects.

3. Limits of Federal Liability. In issuing this permit, the Federal Government does not assume any liability for the following:

a. Damages to the permitted project or uses thereof as a result of other permitted or unpermitted activities or from natural causes.

b. Damages to the permitted project or uses thereof as a result of current or



A-4

future activities undertaken by or on behalf of the United States in the public interest.

c. Damages to persons, property, or to other permitted or unpermitted activities or structures caused by the activity authorized by this permit.

d. Design or construction deficiencies associated with the permitted work.

e. Damage claims associated with any future modification, suspension, or revocation of this permit.

4. Reliance on Applicant's Data: The determination of this office that issuance of this permit is not contrary to the public interest was made in reliance on the information you provided.

5. Reevaluation of Permit Decision. This office may reevaluate its decision on this permit at any time the circumstances warrant. Circumstances that could require a reevaluation include, but are not limited to, the following:

a. You fail to comply with the terms and conditions of this permit.

b. The information provided by you in support of your permit application proves to have been false, incomplete, or inaccurate (see 4 above).

c. Significant new information surfaces which this office did not consider in reaching the original public interest decision.

Such a reevaluation may result in a determination that it is appropriate to use the suspension, modification, and revocation procedures contained in 33 CFR 325.7 or enforcement procedures such as those contained in 33 CFR 326.4 and 326.5. The referenced enforcement procedures provide for the issuance of an administrative order requiring you comply with the terms and conditions of your permit and for the initiation of legal action where appropriate. You will be required to pay for any corrective measures ordered by this office, and if you fail to comply with such directive, this office may in certain situations (such as those specified in 33 CFR 209.170) accomplish the corrective measures by contract or otherwise and bill you for the cost.

6. Extensions. General condition 1 establishes a time limit for the completion of the activity authorized by this permit. Unless there are circumstances requiring either a prompt completion of the authorized activity or a reevaluation of the public interest decision, the Corps will normally give favorable consideration to a request for an extension of this time limit.

Your signature below, as permittee, indicates that you accept and agree to comply with the terms and conditions of this permit.

Thomas K. MacVicar

(PERMITTEE)

Thomas K. MacVicar, Deputy Executive Director

March 9 1990

(DATE)

This permit becomes effective when the Federal official, designated to act for the Secretary of the Army, has signed below.

for Bertf Heimer

(DISTRICT ENGINEER)

Bruce A. Malson

Colonel, U.S. Army

MAR. 1 2 1990

(DATE)

When the structures or work authorized by this permit are still in existence at the time the property is transferred, the terms and conditions of this permit will continue to be binding on the new owner(s) of the property. To validate the transfer of this permit and the associated liabilities associated with compliance with its terms and conditions, have the transferee sign and date below.

(TRANSFEREE)

(DATE)

GENERAL CONDITIONS:

c. Records of monitoring information shall include:

- the date, exact place, and time of sampling or measurements;
- the person responsible for performing the sampling or measurements;
- the date(s) analyses were performed;
- the person responsible for performing the analyses;
- the analytical techniques or methods used; and
- the results of such analyses.

15. When requested by the department, the permittee shall within a reasonable time furnish any information required by law which is needed to determine compliance with the permit. If the permittee becomes aware that relevant facts were not submitted or were incorrect in the permit application or in any report to the department, such facts or information shall be submitted or corrected promptly.

SPECIFIC CONDITIONS:

1. The permittee is hereby advised that Florida law states: "No person shall commence any excavation, construction, or other activity involving the use of sovereign or other lands of the state, title to which is vested in the Board of Trustees of the Internal Improvement Trust Fund or the Department of Natural Resources under Chapter 253, until such person has received from the Board of Trustees of the Internal Improvement Trust Fund the required lease, license, easement, or other form of consent authorizing the proposed use." Pursuant to Florida Administrative Code Rule 16Q-14, if such work is done without consent, or if a person otherwise damages state land or products of state land, the Board of Trustees may levy adminstrative fines of up to $10,000 per offense.

2. If historical or archeological artifacts, such as Indian canoes, are discovered at any time within the project site the permittee shall immediately notify the district office and the Bureau of Historic Preservation, Division of Archives, History and Records Management, R. A. Gray Building, Tallahassee, Florida 32301.

SPECIFIC CONDITIONS:

3. Prior to commencement of work authorized by this permit, the permittee shall notify the Department of Environmental Regulation, Bureau of Wetland Resource Management in Tallahassee, and the Southeast District office in West Palm Beach, in writing of this commencement.

4. After installation of the additional culverts in the S-197, the structure shall initially be operated in accordance with the following schedule:

S-177 HW > 4.10 or S-18C HW > 2.80: 3-84 in. CMP open
S-177 HW > 4.15 or S-18C HW > 3.10: 7-84 in. CMP open
S-177 HW > 4.30 or S-18C HW > 3.30: 13-84 in. CMP open

(HW = Headwater; CMP = culvert)

5. Within 6 months of issuance of this permit, the permittee shall coordinate one or more interagency meetings which include representatives of the Department of Environmental Regulation, Department of Natural Resources, the U.S. Fish and Wildlife Service, Everglades National Park, the U.S. Army Corps of Engineers and any other interested agencies or parties who may desire to participate. The purpose of this coordination effort shall be to fully identify and discuss all issues related to the operation and monitoring of the improved S-197, develop criteria under which discharges will be performed, develop appropriate monitoring criteria to assess impacts of discharge from the structure, and a schedule for implementation. Also within 6 months of permit issuance, the permittee shall prepare and submit to the Bureau of Wetland Resource Management in Tallahassee a plan for operation of the structure and monitoring the effects of the discharge which reflects the results of this interagency coordination effort. Upon its final approval by the Department, the plan shall be included in the permit as a formal modification. The Department shall respond to the permittee within 30 days of receipt of this plan. The permittee shall be responsible for performing or having performed any engineering and other environmental studies necessary to produce or implement this plan.

6. One year prior to the expiration date of this permit, the permittee shall coordinate one or more interagency meetings which include representatives of the Department of Environmental Regulation, Department of Natural Resources, the U.S. Fish and Wildlife Service, Everglades National Park, the U.S. Army Corps of Engineers and any other interested agencies or parties who may desire to participate. The purpose of these meetings shall be to review all monitoring data compiled in conformance with the plan specified in Specific Condition No. 4 above and develop recommendations concerning any long-term

SPECIFIC CONDITIONS:
agreements which may be necessary to govern the operation of the S-197 pending implementation of a comprehensive long-term solution to the C-111 issue and point source discharges to Manatee Bay. The permittee shall enter into such a long-term agreement with the Department if needed prior to expiration of the permit.

7. Prior to the start of excavation for improvements to the C-111 Gaps, the permittee shall designate the site of the upland disposal area and provide details of construction methodology to transport the excavated material in a manner which will protect both water quality and wetland areas. Written approval must be received from the Department prior to beginning construction of the gaps.

8. Best management practices for turbidity control shall be utilized at all times during construction of project components to ensure that violations of State Water Quality Standards do not occur as a result of construction.

MONITORING REQUIRED:
While operating the S-197 in accordance with Specific Condition No. 4 and prior to implementation of the plan developed in response to Specific Condition No. 5, the permittee shall keep appropriate records of all discharges through the structure which include but are not limited to water levels at the S-177, S-18C and S-197, times and numbers of culverts open at the S-197 and duration of discharge, and estimations of volumes of water discharged. These data shall be available to the interagency review participants during development of the plan required by Specific Condition No. 5.

Recommended by John M. Bossart

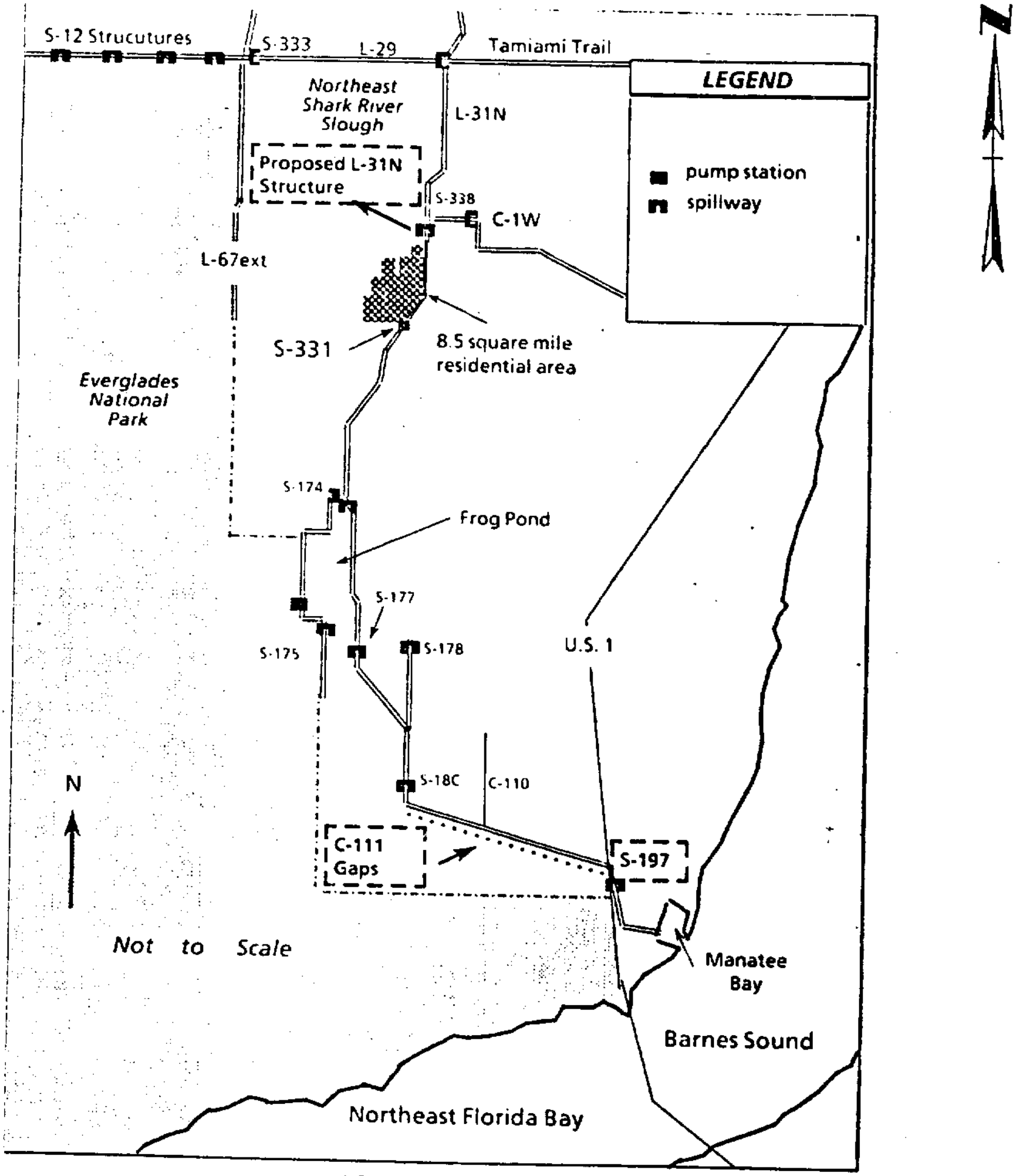
STATE OF FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

Dale Twachtmann
DALE TWACHTMANN, Secretary

____ pages attached.



A-11




LOCATION MAP

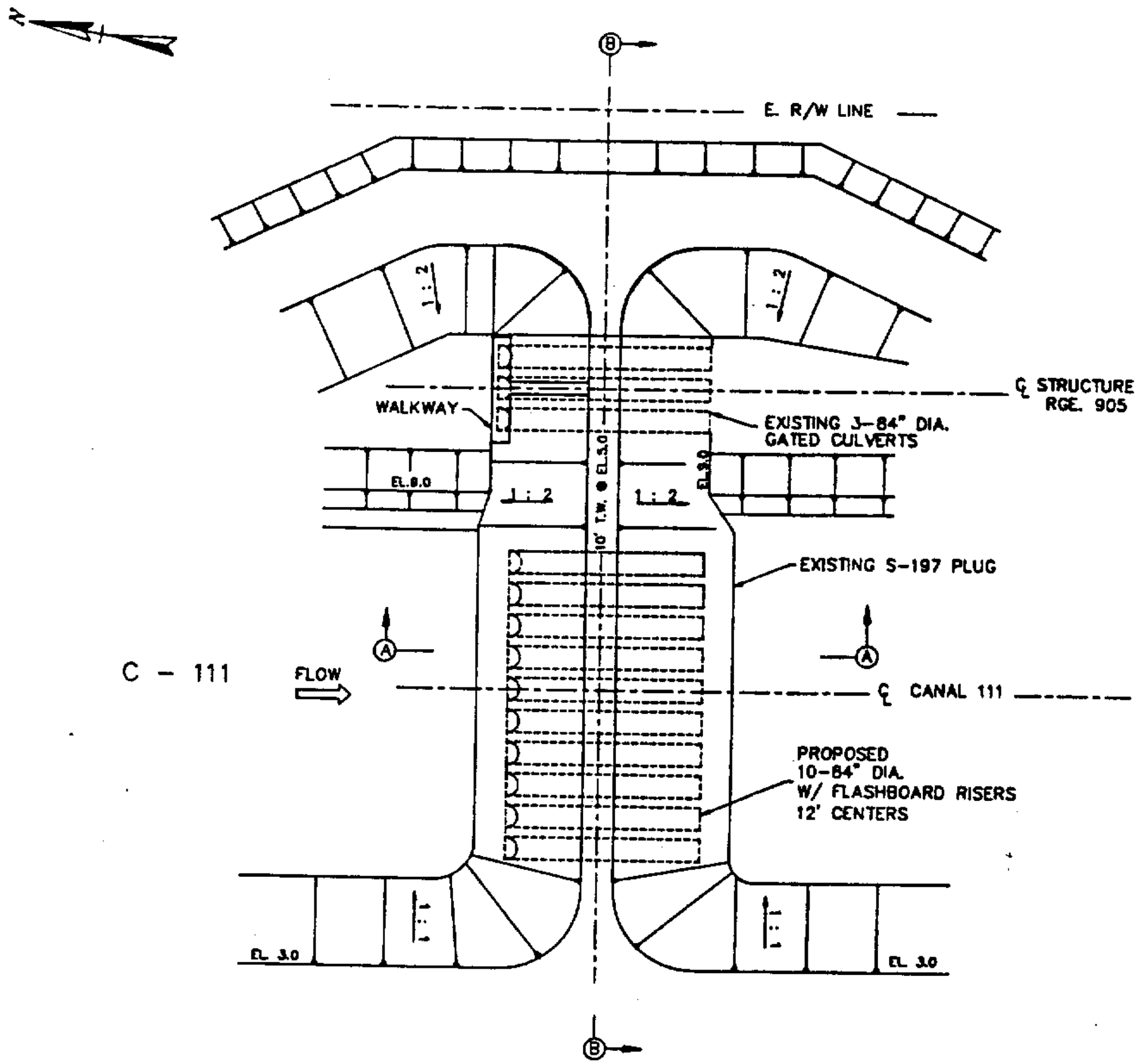
SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33402

C-111 INTERIM PROJECT

| DRAWN | CHKD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| | | | | | 1 of 8 |

89IPC-20492

A-17




LEGEND

| | |
|---|---|
| TT | EXISTING SLOPE |
| — | DIRECTION OF SLOPE |
| 1:2 | RATIO OF SLOPE (1 VERT. ON 2 HORZ.) |
| ---- | CENTERLINE |

## SITE PLAN

NTS

APPROX.SCALE: 1"=60'

S-197 STRUCTURE PLAN VIEW

**SOUTH FLORIDA WATER MANAGEMENT DISTRICT**

3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33402

C - 111 INTERIM PROJECT

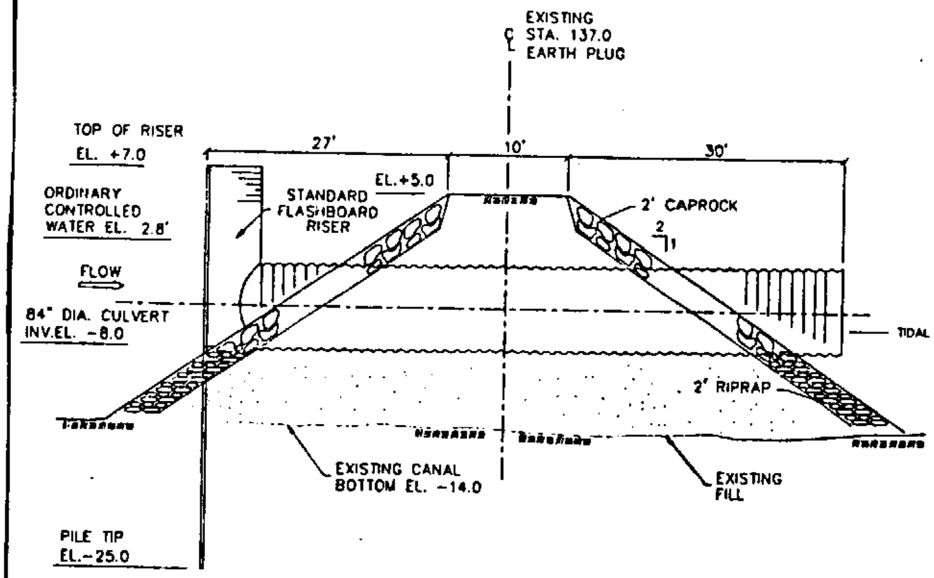
| DRAWN | CHKD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| RJB | RER | 4/8/89 | NTS | | 2 OF 8 |

DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS P.E.
FLORIDA ENGINEERS CERTIFICATE #11572

Robert E Rodgers

DATE May 25, 1989

89IPC-20492




SECTION A-A
NTS

S-197 STRUCTURE - SECTION A-A

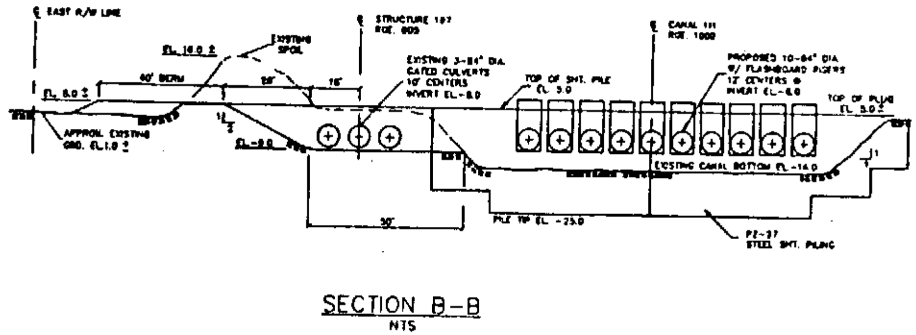
DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS P.E.
FLORIDA ENGINEERS CERTIFICATE #11572

DATE May 25, 1989

SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33406

C - 111 INTERIM PROJECT

| DRAWN | CHKD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| RJB | RER | 9/24/88 | NTS | | 3 OF 8 |




S-197 STRUCTURE - SECTION B-B

DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS P.E.
FLORIDA ENGINEERS CERTIFICATE #11572

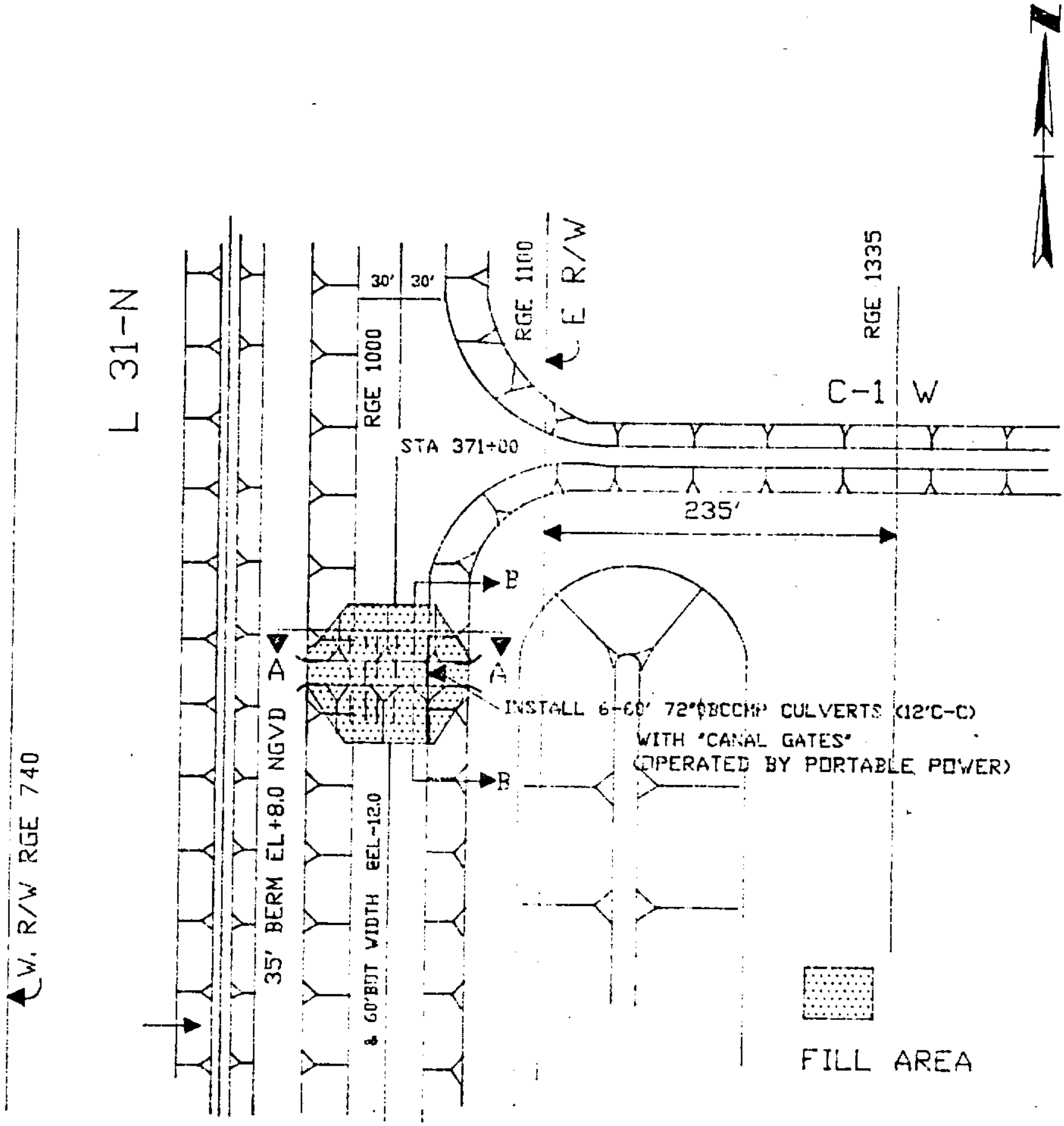
DATE May 25, 1989

SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33406

C - 111 INTERIM PROJECT

| DRAWN | CHKD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| RJB | RER | 9/28/88 | NTS | | 4 OF 8 |

89 IPC - 20492




L-31N STRUCTURE PLAN VIEW

DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS, P.E.
FLA. ENGINEER CERT. NO. 11572

Robert E. Rodgers

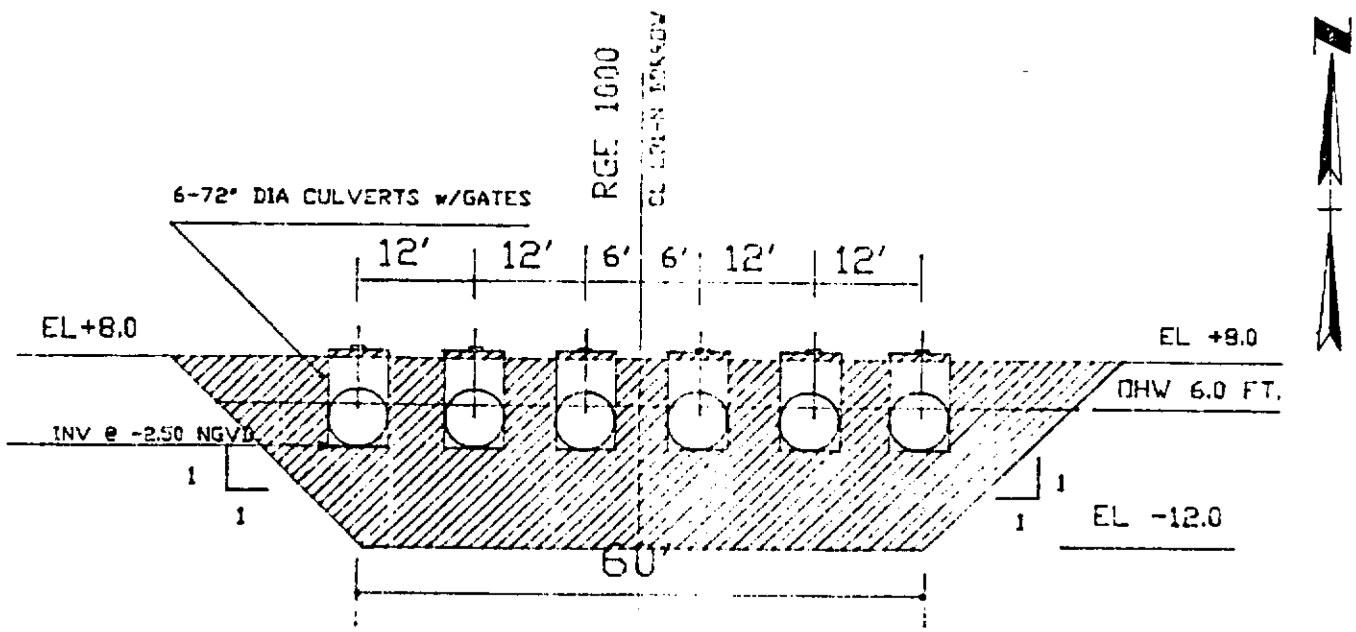
DATE: May 25, 1989

SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33402

C-111 INTERIM PROJECT

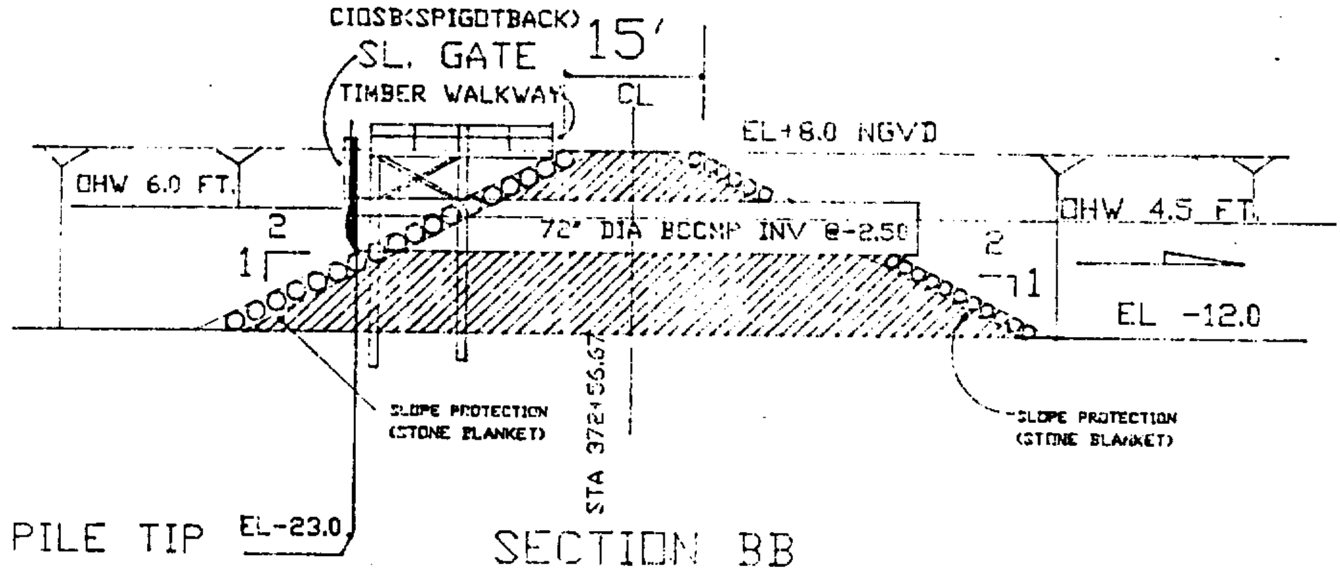
| DRAWN | CKD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| SPM | | 5/24/89 | 1"=100' | | 5 OF 8 |

89 EPC-20492




AREA TO BE FILLED

SECTION AA
(1"=20')




SECTION BB
(1"=20')

L-31N STRUCTURE CROSS SECTION

DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS, P.E.
FLA. ENGINEER CERT. NO. 11572

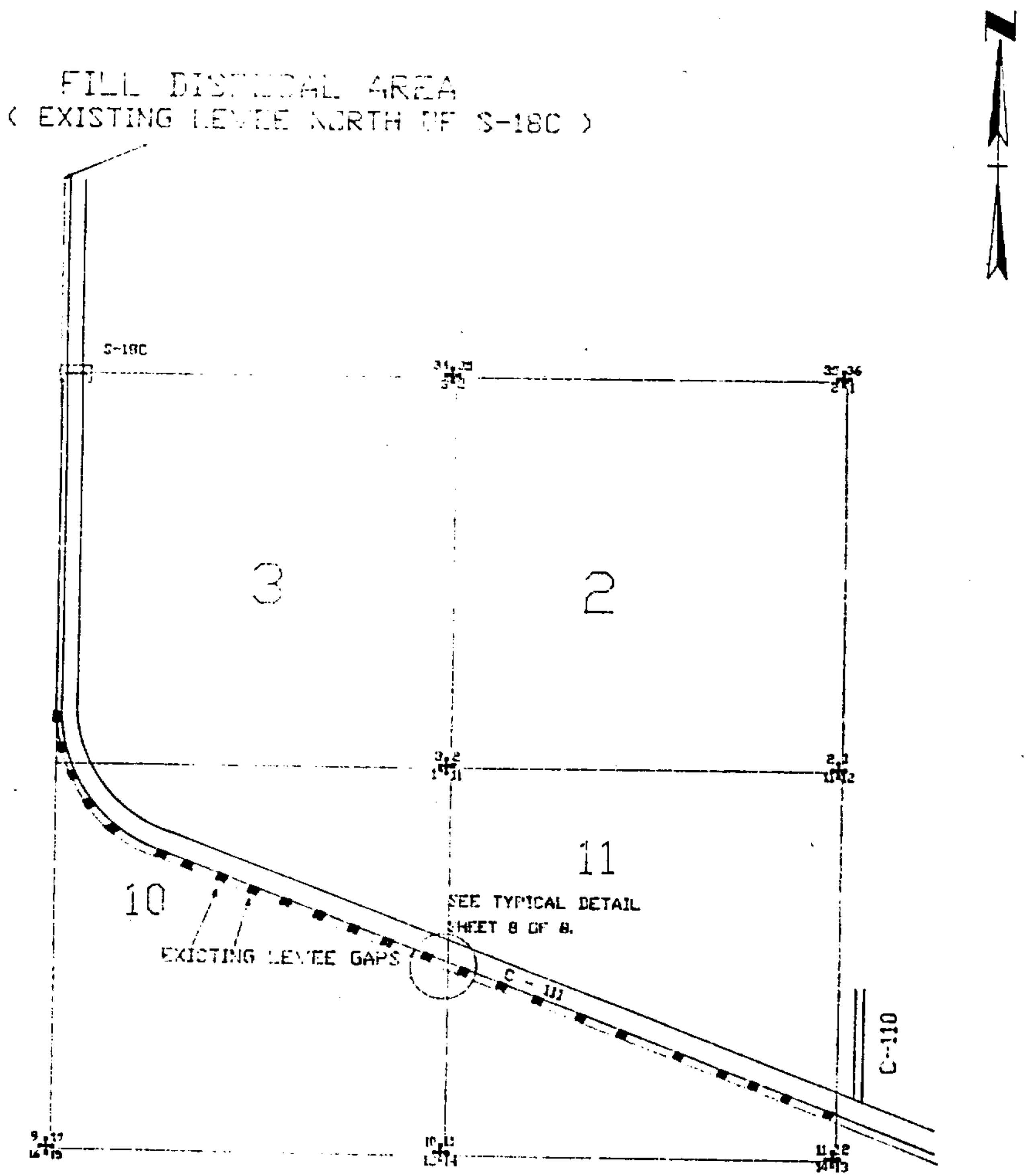
DATE: May 12, 1989

SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33402

C-111 INTERIM PROJECT

| DRAWN | CHKD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| SDM | | 5/24/89 | 1"=20' | | 6 OF 8 |

89IPC-20492




C-111 LEVEE GAP PLAN VIEW

DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS, P.E.
FLA. ENGINEER CERT. NO. 11572

Robert E. Rodgers

DATE: May 25, 1989

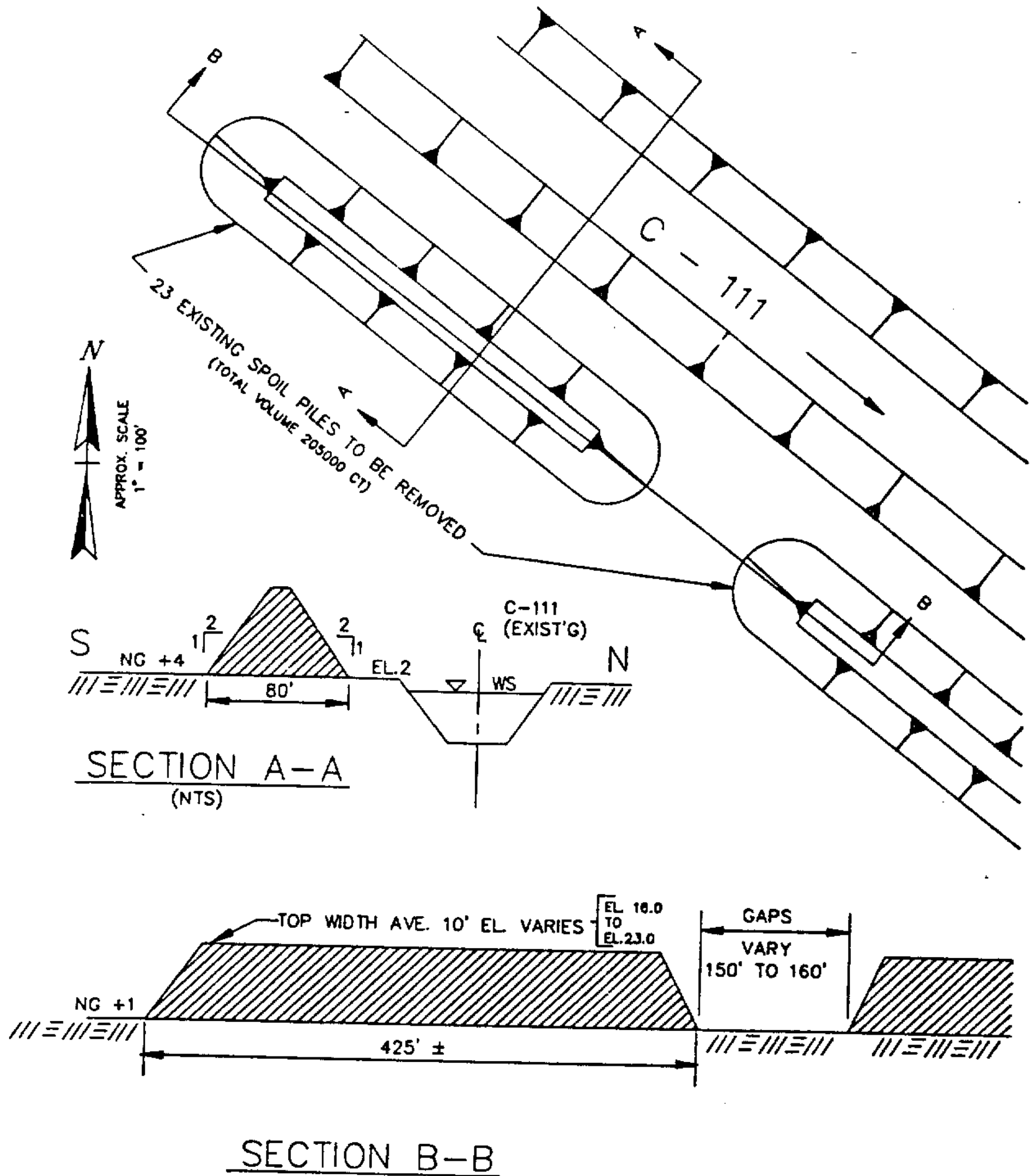
SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33402

C-111 INTERIM PROJECT

| DRAWN | CH'KD | DATE | SCALE | DRAWING NO. | SHEET |
|---|---|---|---|---|---|
| [illegible] | | 5/24/89 | NTS | | 7 OF 8 |

89IPC-20492

A-1




C-111 LEVEE GAP DETAIL

**SOUTH FLORIDA**
**WATER MANAGEMENT DISTRICT**
3301 GUN CLUB ROAD, WEST PALM BEACH, FLORIDA 33402

C - 111 INTERIM PROJECT

89 IPC-20492

| DRAWN | CHKD | DATE | SCALE | DRAWING NO. | SHEE |
|---|---|---|---|---|---|
| RJB | RER | 9/26/88 | NTS | | 8 OF |

DESIGNED UNDER SUPERVISION OF
ROBERT E. RODGERS P.E.
FLA. ENGINEERS CERT. 11572

Robert E Rodgers

DATE May 25, 1989

## TABLE I
## PROJECT COMPONENT SUMMARY

| PROJECT COMPONENT | DESCRIPTION | PURPOSE | EXCAVATION | FILL | WETLAND IMPACTS |
|---|---|---|---|---|---|
| L-31 N Structure | 6 72" Diameter culverts @ invert elvation-2.5 ft. with gates. | Increase canal control elevation from 4.5 ft. to 5.5-6.0 ft. in order to decrease seepage from N. Shark River Slough. Also, allow diversion to C-1W. | 0 | 3,260 cu yds | 0 |
| C-111 Gap Improvements | Removal of (23) 425 linear ft. levee runs between existing 150 ft. gaps. Excavate205,000 cy. (425x80x18 + to 1.0 ft. el.) | Provide more uniform overland flow to E.N.P. Panhandle. Reduce discharge at S-197. | 205,000 cu yds | 0 | *18.0 wetland acres created |
| S-197 Culverts | 10-84" diameter culverts @ invert elvation-8.0 ft. with flashboard risers. | Eliminate need to pull plug. Reduce turbidity, siltation and salinity change impacts on Manatee Bay & Barnes Sound. | 750 cu yds | 0 | 0 |
| S-197 Operation Revision | Gradual opening of S-197 culverts as opposed to immediate full flow in response to major storm events. | Reduce salinity change impacts to Manatee Bay and Barnes Sound. | N/A | N/A | N/A |
| TOTAL | | | 205,750 cu yds | 3,260 cu yds | 18 acres created |

89IRC-20492
A1

Dewr

United States Department of the Interior
FISH AND WILDLIFE SERVICE
P.O. BOX 2676
VERO BEACH, FLORIDA 32961-2676

September 25, 1989

Mr. Gary Goforth
South Florida Water Management District
P.O. Box 24680
West Palm Beach, FL 33416-4680

Dear Mr. Goforth:

I appreciated the opportunity to discuss the District's proposed improvements to the C-111 Canal system and, our suggestion for a test of the feasibility of directing canal flows into the marsh east of C-111 and west of U.S. Hwy 1. As I mentioned, we had recommended that the Corps of Engineers excavate a "spreader canal" for this purpose, but their hydrologists felt that calculations regarding flows through such a structure would be inaccurate. They suggested that the District might install a culvert and cut a ditch for a small scale test of this idea.

The District previously investigated the removal of portions of the levee between the canal and the marsh as a "demonstration project", but further south, nearer to 18-C than we are proposing. I feel that introduction of canal waters should be made as far to the north as possible.

For this demonstration project I propose that one or a pair of 36 inch culverts be installed at the same location tendered to the Corps of Engineers (at the northern boundary of District owned land) and that a shallow ditch be cut to the east, perhaps by use of one of the rotary ditchers employed by Mosquito Control agencies. The enclosed survey line along the Spreader Canal route shows some ground elevations around 1.5 to 2.5 feet NGVD. Since 18-C often is held at 2.6 feet, water should pass through the culvert(s) and over the banks of the ditch into these depressions in the eastern marsh, ultimately exiting across C-111 at the south of this impounded area.

I would appreciate input from you or your staff on any design elements to increase the likelihood of environmental benefit due to reintroduction of flowing water to this eastern marsh, expanding hydroperiod and filtering waters prior to passage into Everglades National Park.

Sincerely,

Arnold Banner

Arnold Banner, Ph.D.

Encl.

FISH AND WILDLIFE SERVICE
C-111 SPREADER CANAL ALTERNATIVE

This proposal builds upon the basic system offered in the Corps' draft GDM. It assumes that new structures and wider canal sections guarantee flood protection, but release floods only into Manatee Bay or Florida Bay. The Park's recent proposal for pumping floodwaters into Taylor Slough could complement the spreader canal. Both may offer enhancement opportunities for fish and wildlife, including endangered species and serve as alternative discharge routes to handle flood releases. If feasible, the spreader canal could significantly increase management options for wetlands in the project area (Figure 1, aerial of proposed work).

At present, stages in the eastern marsh (between C-111 and U.S. 1) are controlled by local rainfall, runoff from the ridge and slope to the north, and exchange with C-111 via seepage and the culverts at the south end of the marsh. We propose incorporating this wetland into an eastern flow-way by directing canal headwaters of S-18C through a new structure on the east side of C-111E. Structure 18C of course, would remain operative for flood releases or to satisfy water needs of the Park's panhandle, should losses in the flow-way be excessive.

<u>FEATURES</u> (see Figure 2)

1) In order to avoid raising stages on privately owned lands north of the eastern marsh, rainfall and runoff north of the proposed spreader will be diverted to the east, under U.S. 1. This will offer the associated benefit of restoring headwaters cut off by construction of U.S. 1 and Card Sound Road. We anticipate that Department of Transportation (DOT) will install banks of culverts to transfer water under the highway; they have already offered to install culverts as part of the widening of the road (Figure 3).

2) An east/west levee exists along most of the boundary of these South Florida Water Management District (SFWMD) lands. The levee is 4 feet to 6 feet NGVD elevation, adequate to keep water from the proposed spreader canal (see item 3) from affecting private lands. A collector ditch should be excavated north of this levee to insure adequate delivery of runoff from the north, over to U.S. 1. We propose that this be part of the DOT mitigation.

3) A lower levee and swales are found on the proposed alignment of the spreader canal. These should be excavated to appropriate depth and width for conveyance and distribution of flood waters. It may be necessary to leave a berm along the north side of this canal adjacent to the County prison in one of the eastern quarter sections.

This entire east/west alignment was surveyed for a potential levee in the Corps 1959 L-31 GDM (Figure 4). Natural ground elevations between C-111E (labelled as S.W 207 Ave. Canal) and U.S.1. ranged from 1.5 feet to 2.5 feet, suggesting that overflow could readily be controlled through manipulation of S-18C headwater stages.

4) The northern ends of C-109 and C-110 should be plugged, and segments of the canal levees should be removed to prevent entrainment of sheetflow, and to provide dry season refugia. Sheetflow would be enhanced by cutting of gaps in the salt-line levee east of S-18C.

5) A structure at the junction of the spreader and C-111E would allow control of spreader stages somewhat independently of operations of S-18C. The structure should be sized to allow potential use of the spreader to disperse flood flows.

6) This section (27) has been designated as part of the critical habitat for the Cape Sable seaside sparrow. Surveys in 1981 and 1985 did not indicate any use of this area by sparrow. Hydrographs for 1985 - 1987, and more recent field inspection show this section to have longer hydroperiod than typical of sparrow habitat. Therefore, management of this eastern marsh will not be likely to cause "adverse modification" to critical habitat.

It would seem reasonable to use the spreader to supply scheduled deliveries to the Park panhandle. Quantities reaching the Park could be measured as flows through the existing eastern marsh culverts, rather than at S18-C. If loss of water by evapo-transpiration in this eastern marsh are significant, it may be necessary to provide supplementary deliveries from Water Conservation Area 3A to compensate for this and meet the minimum delivery scheduled for the Park.

Enclosures:

- Figure 1; aerial view of work area.
- Figure 2; spreader canal features
- Figure 3; DOT culvert proposal map
- Figure 4; Corps survey along proposed spreader alignment

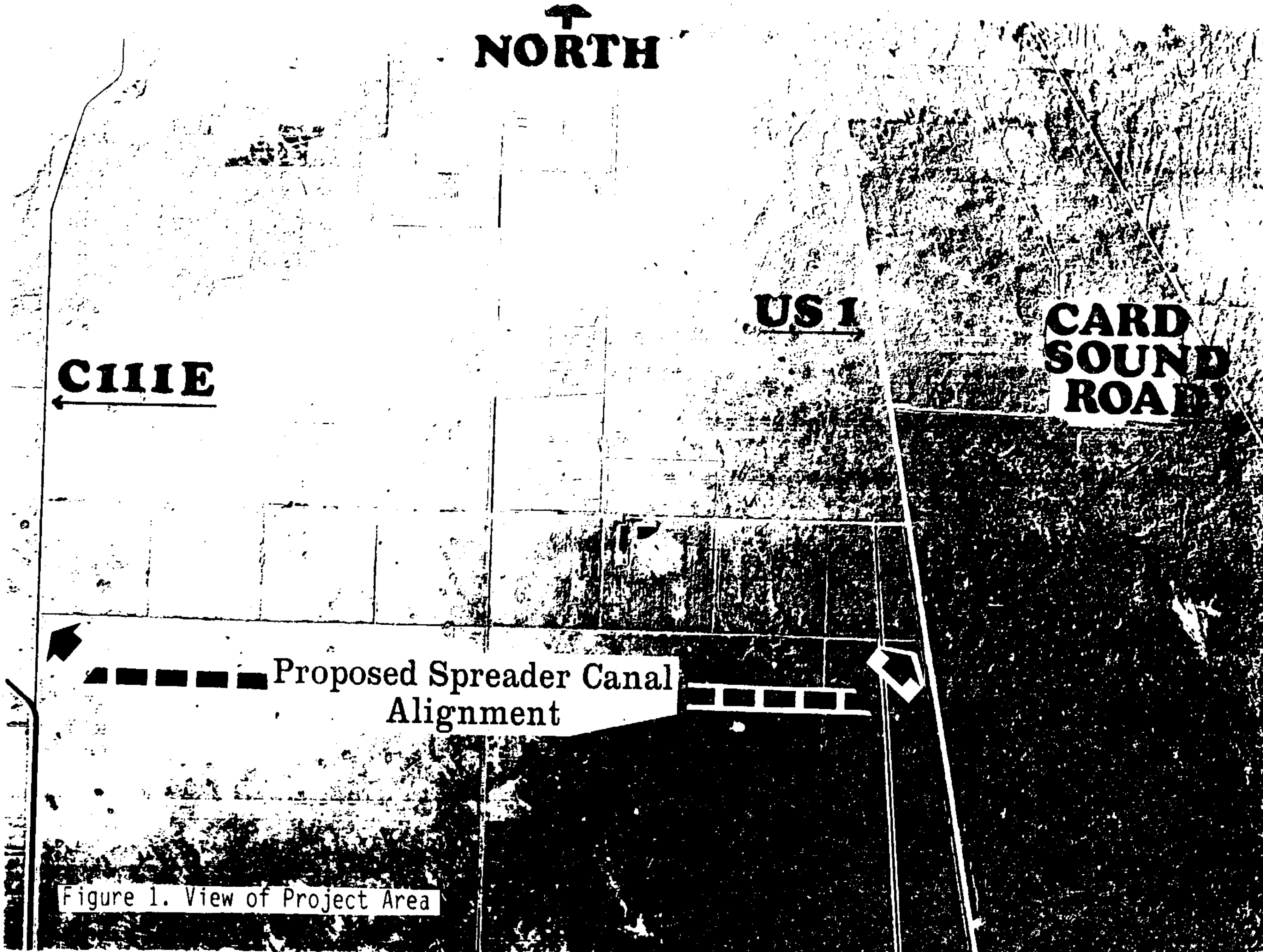



Figure 1. View of Project Area

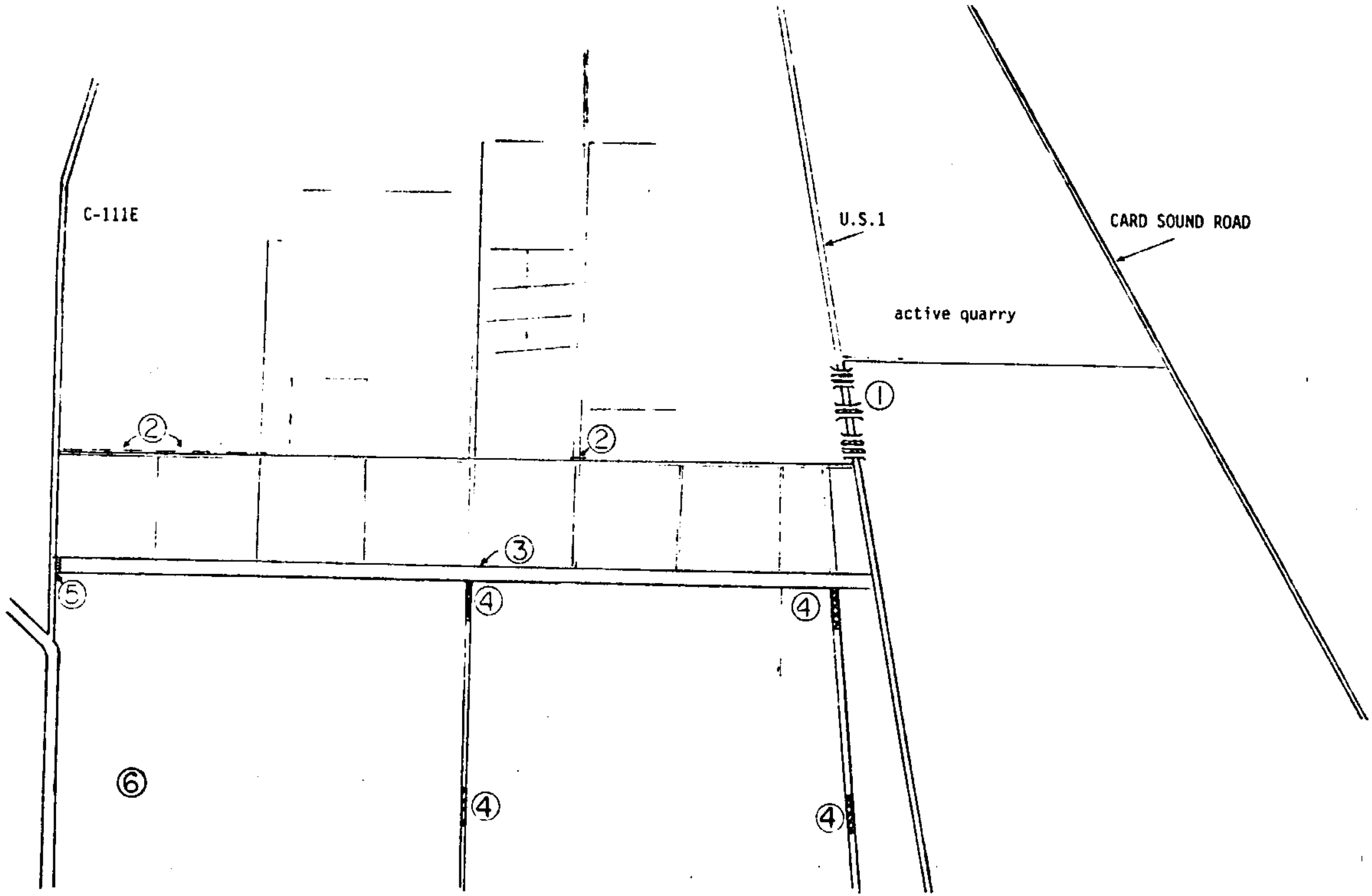



Figure 2. Spreader canal features ; numbers refer to paragraphs in text.

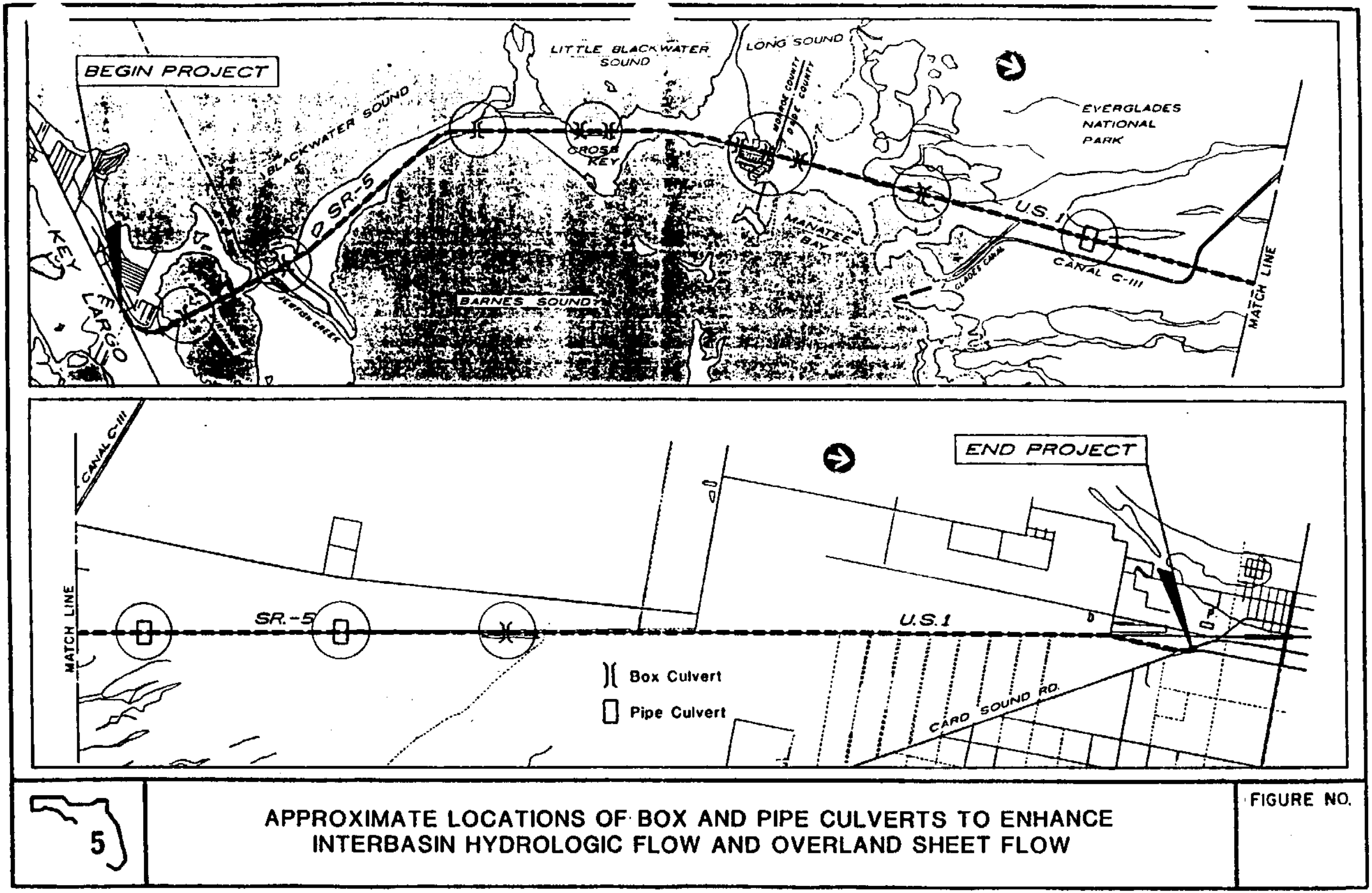
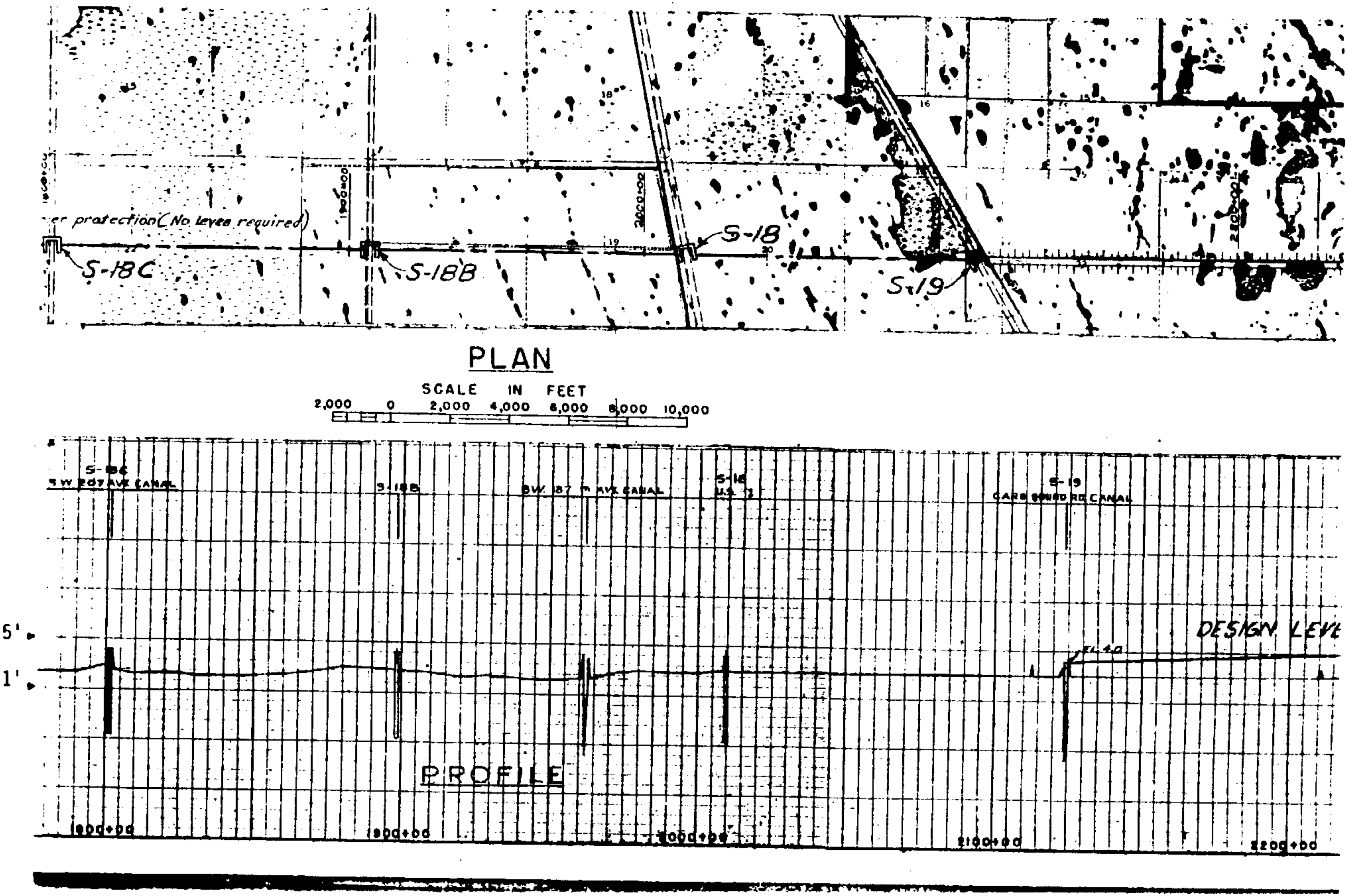



Figure 3. Initial D.O.T. proposal for culverting under U.S.1; figure 2 shows current proposed locations.

Figure 4. Survey along spreader canal route.



Appendix 2. Interagency meetings November 29, 1989 and March 21, 1990. Meeting announcements, summaries and written comments submitted by agencies.

Part A. November 29, 1989 Meeting

Part B. March 21, 1990 Meeting

Part C. Written Comments



A-1

Part A. November 29, 1989 Meeting

SAME LETTER SENT TO ATTACHED MAILING LIST.

*Protecting South Florida's Water Resources for 40 Years*
*1949-1989*

# South Florida Water Management District

P.O. Box 24680 • 3301 Gun Club Road • West Palm Beach, FL 33416-4680 • (407) 686-8800 • FL WATS 1-800-432-2045

October 23, 1989

Mr. Dan Dunford
Florida Game and Fresh
Water Fish Commission
551 North Military Trail
West Palm Beach, FL 33415

Dear Mr. Dunford:

On November 2 at 1:30 p.m. the South Florida Water Management District (District) and U.S. Army Corps of Engineers have scheduled a joint interagency meeting to discuss the status of the C-111 GDM and C-111 Interim Plan. The meeting will be held in the Regulation South Conference Room at the District's headquarters in West Palm Beach. The enclosed agenda highlights some of the topics that will be discussed.

The District has recently been granted a permit from the Florida Department of Environmental Regulation to proceed with the Interim C-111 Plan. District staff are making final preparations to implement this plan and would value your agency input. Representatives from the U.S. Army Corps of Engineers will make a status report on the long-term regional solutions proposed in the C-111 General Design Memorandum.

If you have any questions, please contact Dewey Worth at (407) 687-6605.

Sincerely,

Tom

Thomas K. MacVicar
Deputy Executive Director
Executive Office

TKM/DFW/tcs
Enclosure

c: Dewey Worth

bc: Tony Federico
Jim Harvey
Dick Rogers

A-3

ATTACHED LETTER SENT TO THE FOLLOWING:

Mr. Dan Dunford
Florida Game and Fresh
Water Fish Commission
551 North Military Trail
West Palm Beach, FL 33415

683-0748

Mr. John Renfrow, Director
Dade County Department of
Environmental Resource Management
Metro Dade Center
111 N. W. First Street
Miami, FL 33128

Ms. Susan Markley
Dade County Department of
Environmental Resource Management
Metro Dade Center
111 N.W. First Street
Miami, FL 33128

Mr. Scott Benyon
Department of Environmental
Regulation
Suite A
1900 South Congress Avenue
West Palm Beach, FL 33415

Mr. Herb Zebuth
Department of Environmental
Regulation
Suite A
1900 South Congress Avenue
West Palm Beach, FL 33415

Ms. Karen Steidenger
Chief of Marine Research
Florida Department of Natural Resources
Marine Research Institute
100 Eighth Avenue S.E.
St. Petersburg, FL 33701

Mr. Nat Reed
P. O. Box 375
Hobe Sound, FL 33475

Mr. Ken Haddad
Florida Department of Natural Resources
Marine Research Institute
100 Eighth Avenue S.E.
St. Petersburg, FL 33701

813-896-8626

AGENDA

JOINT INTERAGENCY MEETING ON C-111

NOVEMBER 29, 1989

1:30 - 3:30 STATUS UPDATE C-111 PLANS

* SFWMD INTERIM PLAN

  A. PROJECT DESIGN OVERVIEW

  B. SCHEDULE FOR CONSTRUCTION

  C. PERMIT STIPULATIONS

  D. MONITORING ISSUES

* PROGRESS REPORT C-111 GDM - COE

  - CONCENSUS ON ALTERNATIVES TO ADDRESS

  - SCHEDULE

# INTERIM C-111 PLAN

PLAN ELEMENTS:

1. MODIFY S-197: ADD 10 - 84 IN CULVERTS AT S-197. TOTAL WILL BE 13 CULVERTS WITH DESIGN CAPACITY OF 2,300 CFS DISCHARGE.

2. OPERATIONAL CRITERIA FOR S-197: BASED ON S-177 AND S-18C HW CONDITIONS:

   S-177 HW > 4.10 OR S-18C HW ) 2.80: OPEN 3 CULVERTS

   S-177 HW > 4.15 OR S-18C HW ) 3.10: OPEN 7 CULVERTS

   S-177 HW > 4.30 OR S-18C HW ) 3.30: OPEN 13 CULVERTS

3. CONSTRUCT NEW STRUCTURE L-31 N: RAISE UPSTREAM STAGES TO 5.5 - 6.0 NGVD

4. WIDEN GAPS IN WESTERN PORTIONS OF SOUTH BERM IN C-111 CANAL

PERMIT REQUIREMENTS:

1. WITHIN 6 MONTHS OF ISSUANCE OF PERMIT, FORM INTERAGENCY COMMITTEE TO:

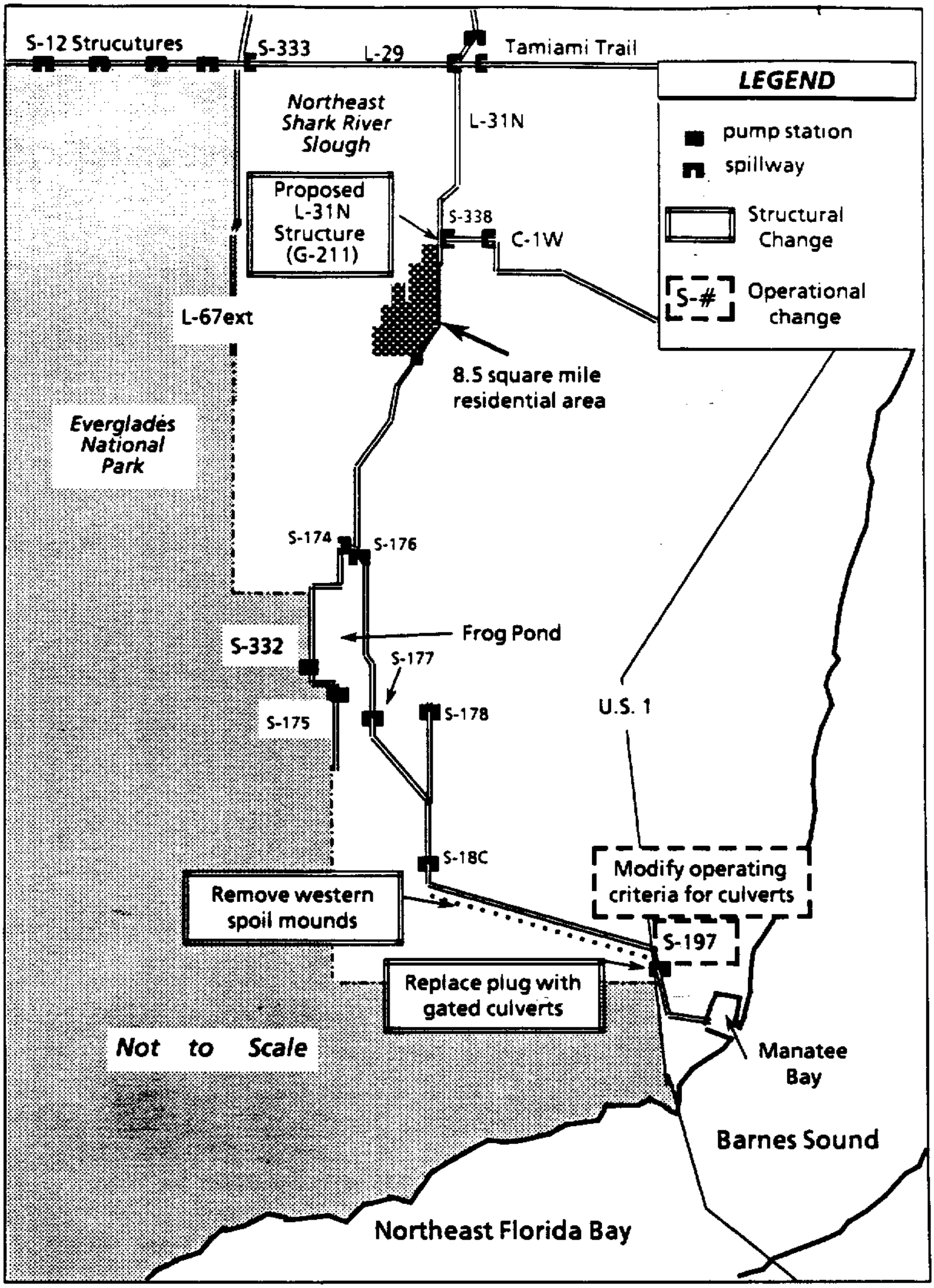
   A. IDENTIFY AND DISCUSS ISSUES RELATED TO OPERATION AND MONITORING OF S-197

   B. DEVELOP CRITERIA UNDER WHICH DISCHARGES WILL BE PERFORMED

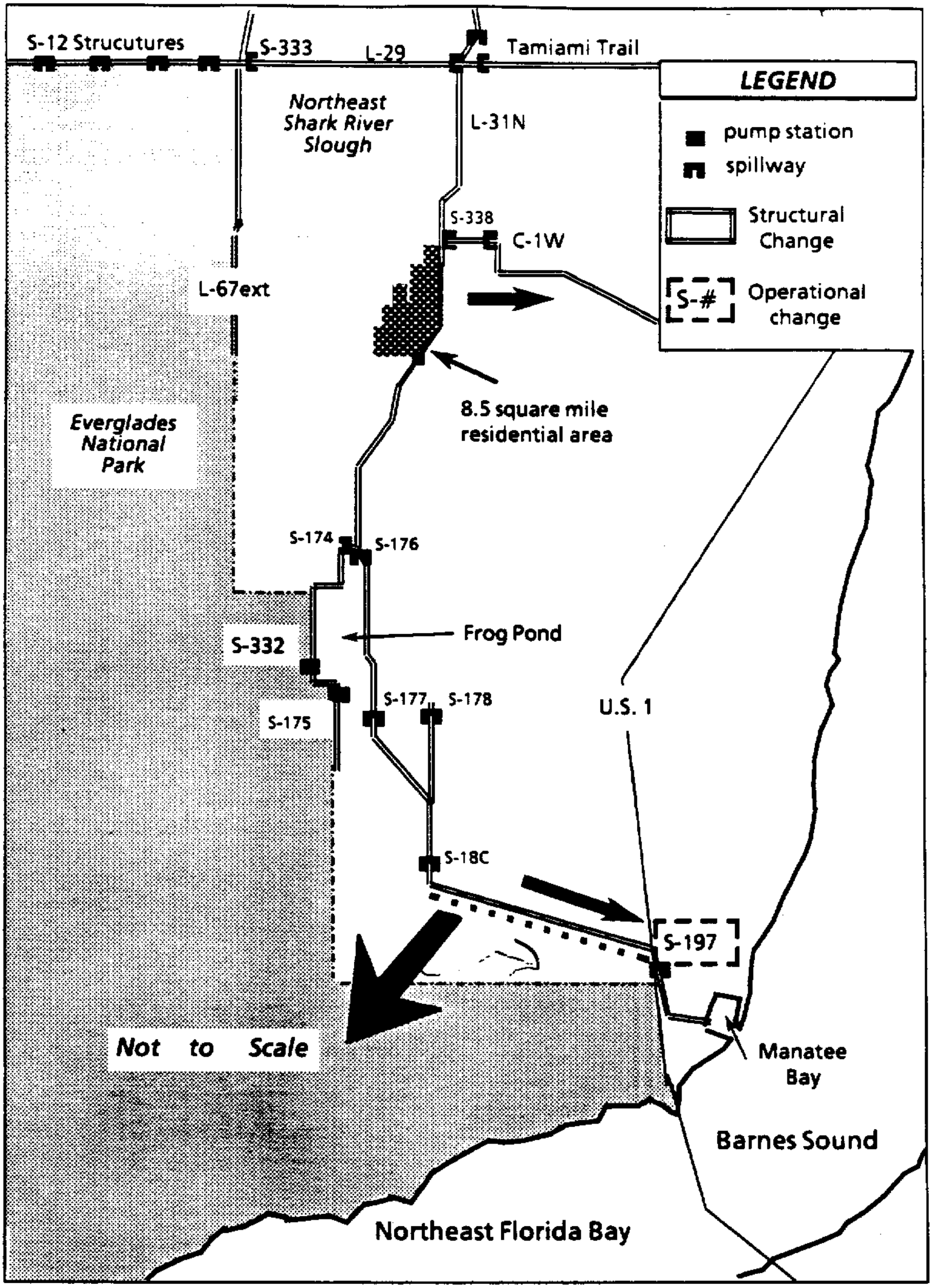
   C. DEVELOP MONITORING CRITERIA TO ASSESS IMPACTS OF DISCHARGES

   D. DEVELOP A SCHEDULE FOR IMPLEMENTATION

2. WITHIN 6 MONTHS, DEVELOP AND SUBMIT A PLAN FOR OPERATION AND MONITORING THAT REFLECTS ABOVE COORDINATION. THIS PLAN WILL BE INCORPORATED IN THE PERMIT AS A FORMAL MODIFICATION.




Generalized diagram of C-111 Basin with location of proposed changes.




Generalized diagram of C-111 Basin with location of proposed changes.

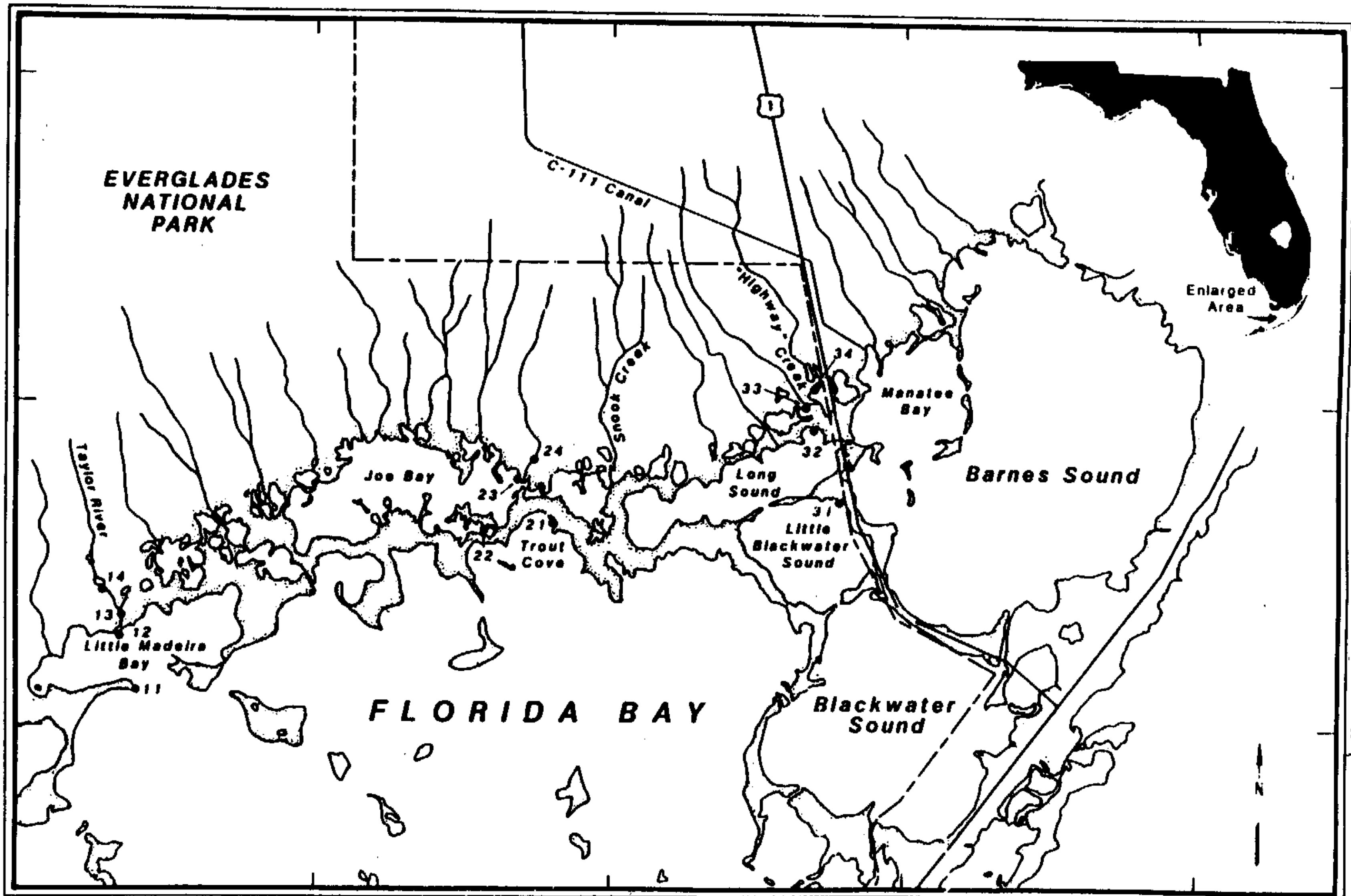



Figure 1. Study Region in Northeastern Florida Bay with Station Numbers Indicated.



A-3

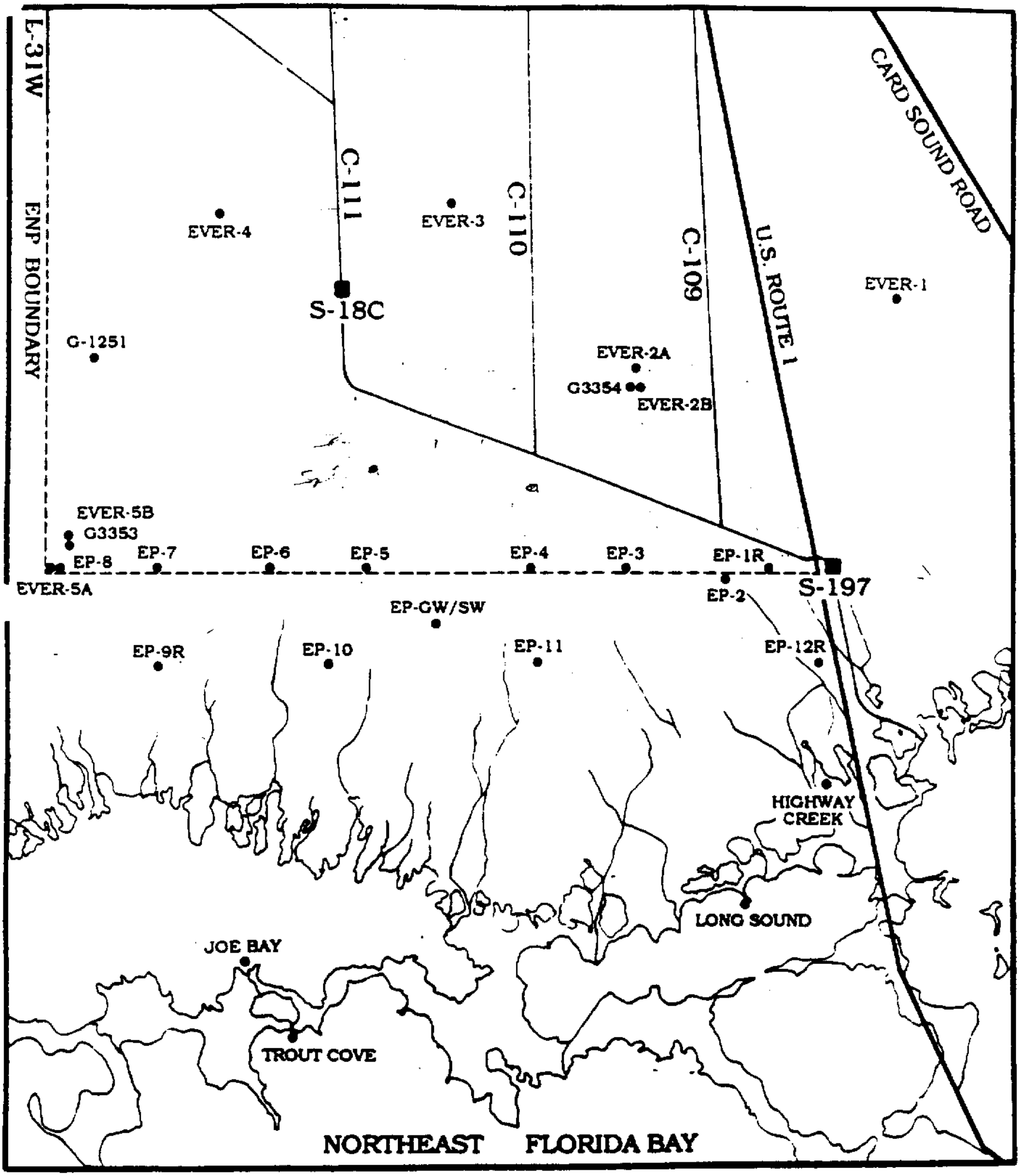



Figure 1. Map of the general study area depicting the locations of the hydrologic monitoring stations in the wetlands adjacent to the lower C-111 canal.

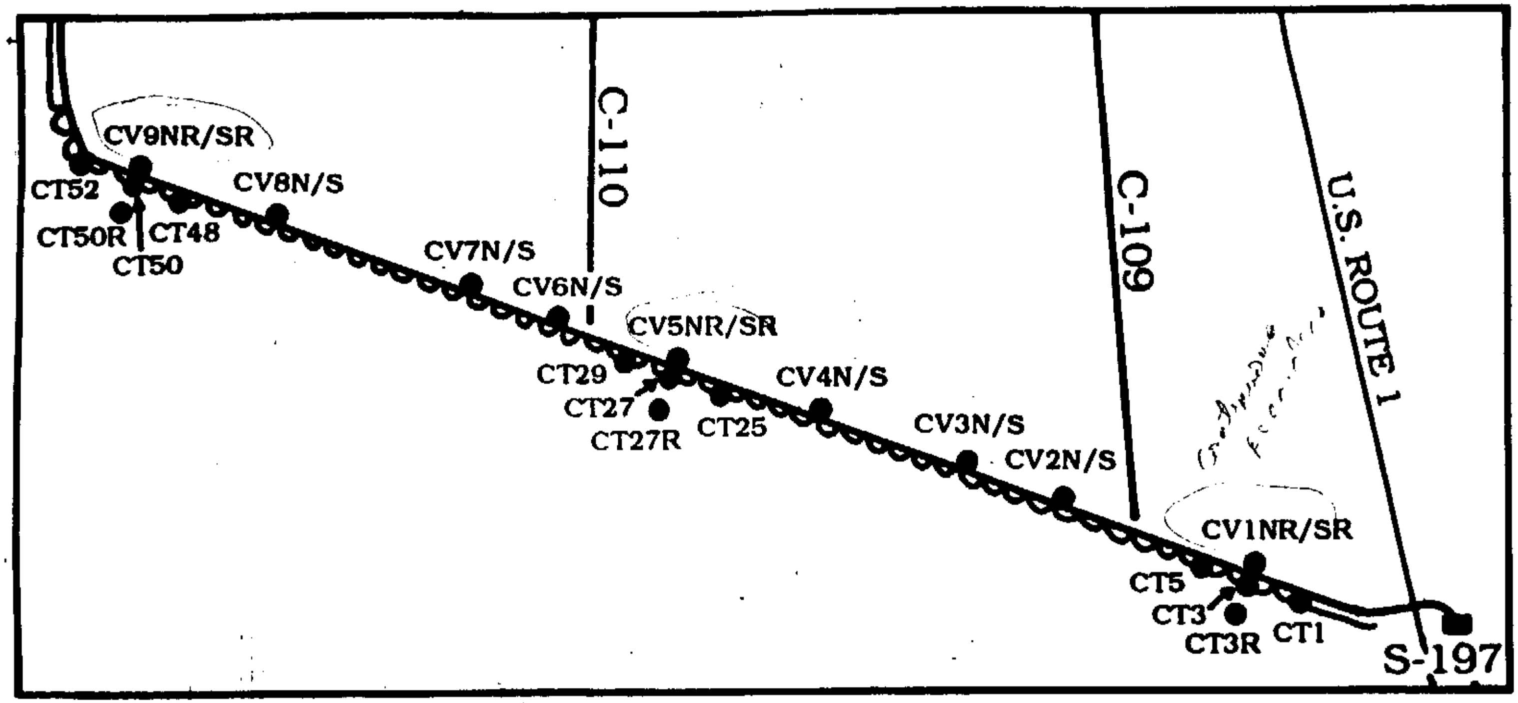
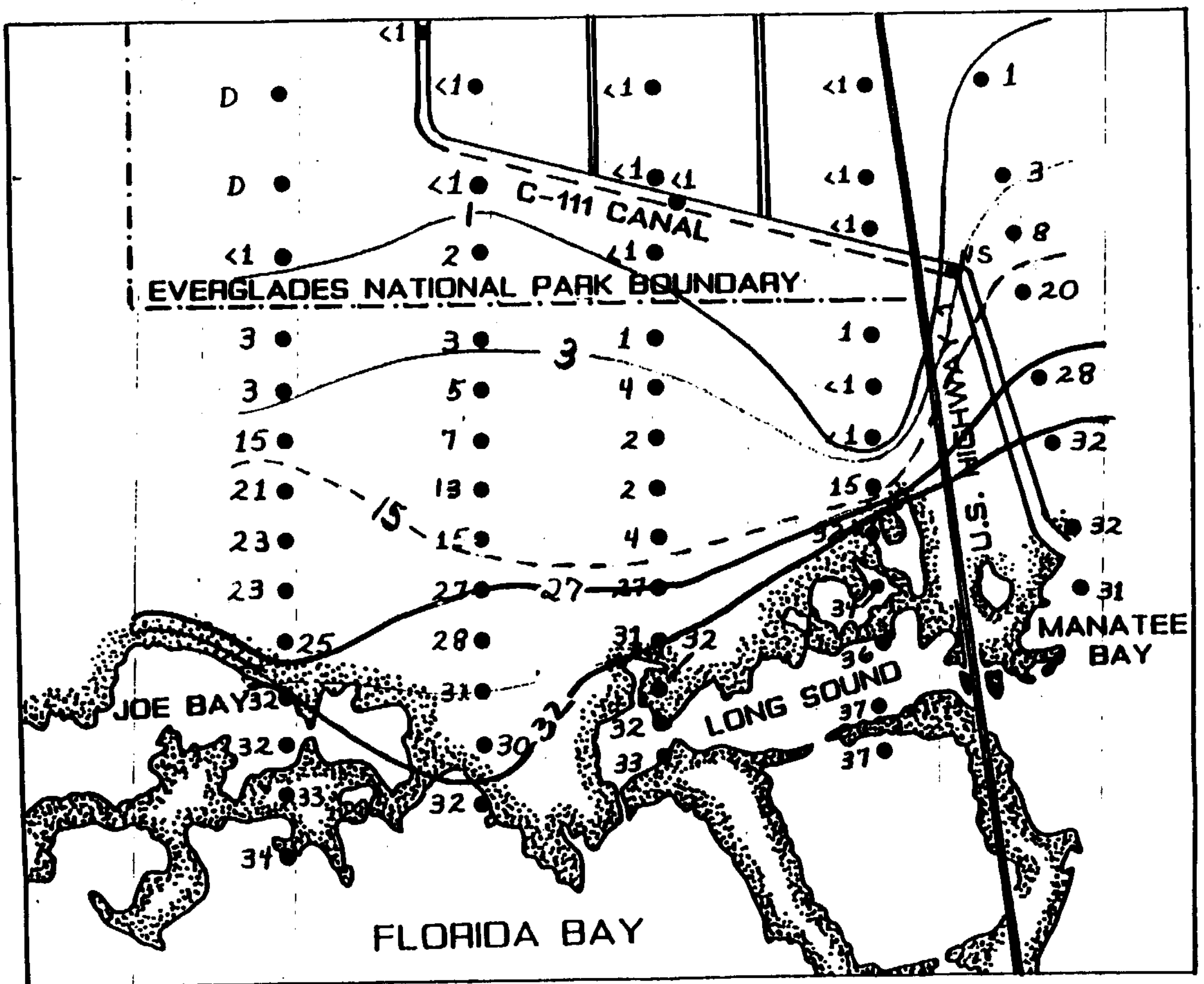



Figure 2. Detailed map of the lower C-111 canal depicting the location of the hydrologic monitoring network installed as part of this study.




SALINITY (ppt)

D = D[illegible] MARSH

NS = NOT SAMP[illegible]

FIGURE [illegible] 19 DRY SEASON SALINITY DATA, C-111 BASIN, JUNE 10-11, 1986.

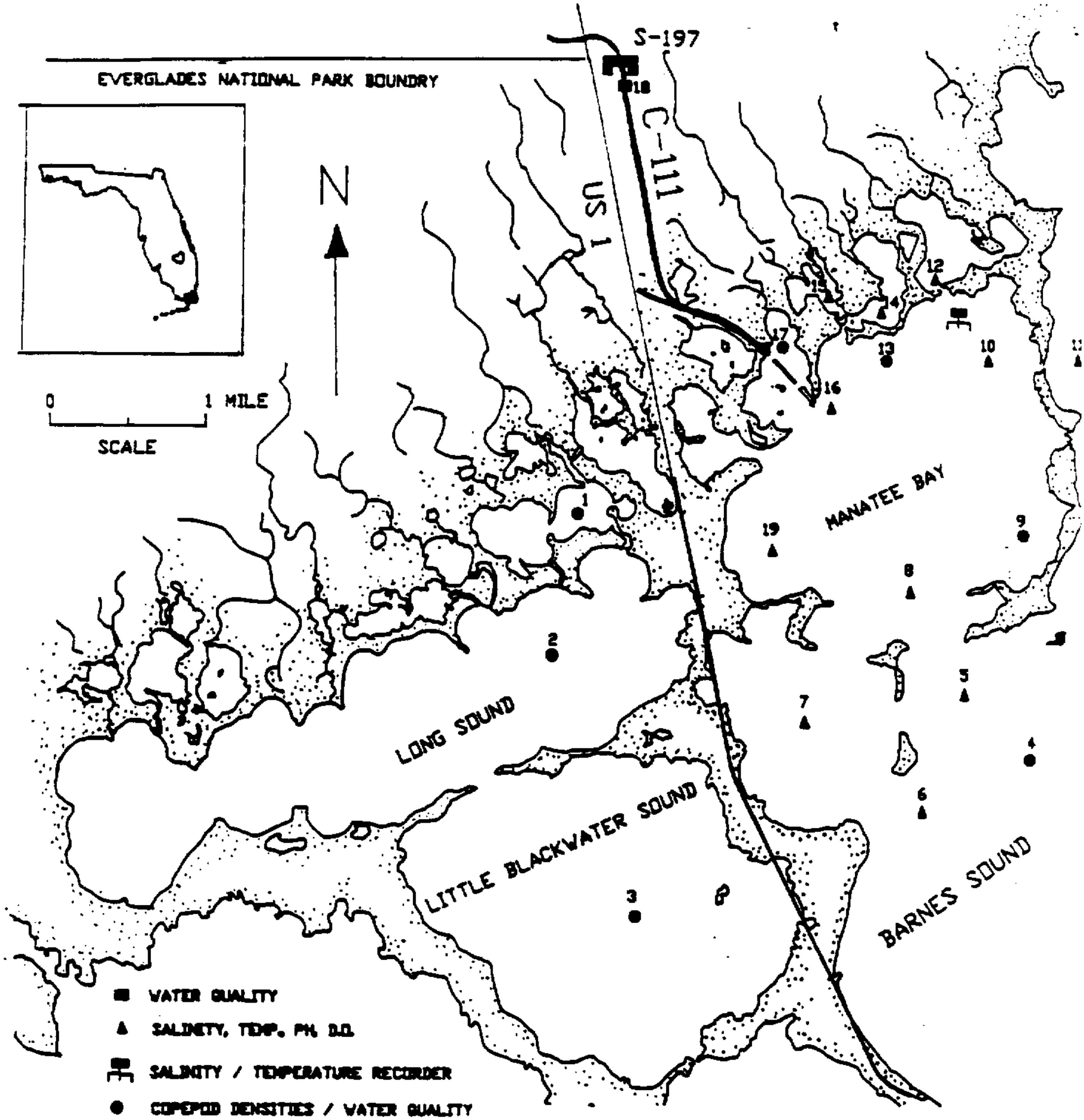



FIGURE 1. ESTUARINE STUDY AREA IN SOUTH FLORIDA



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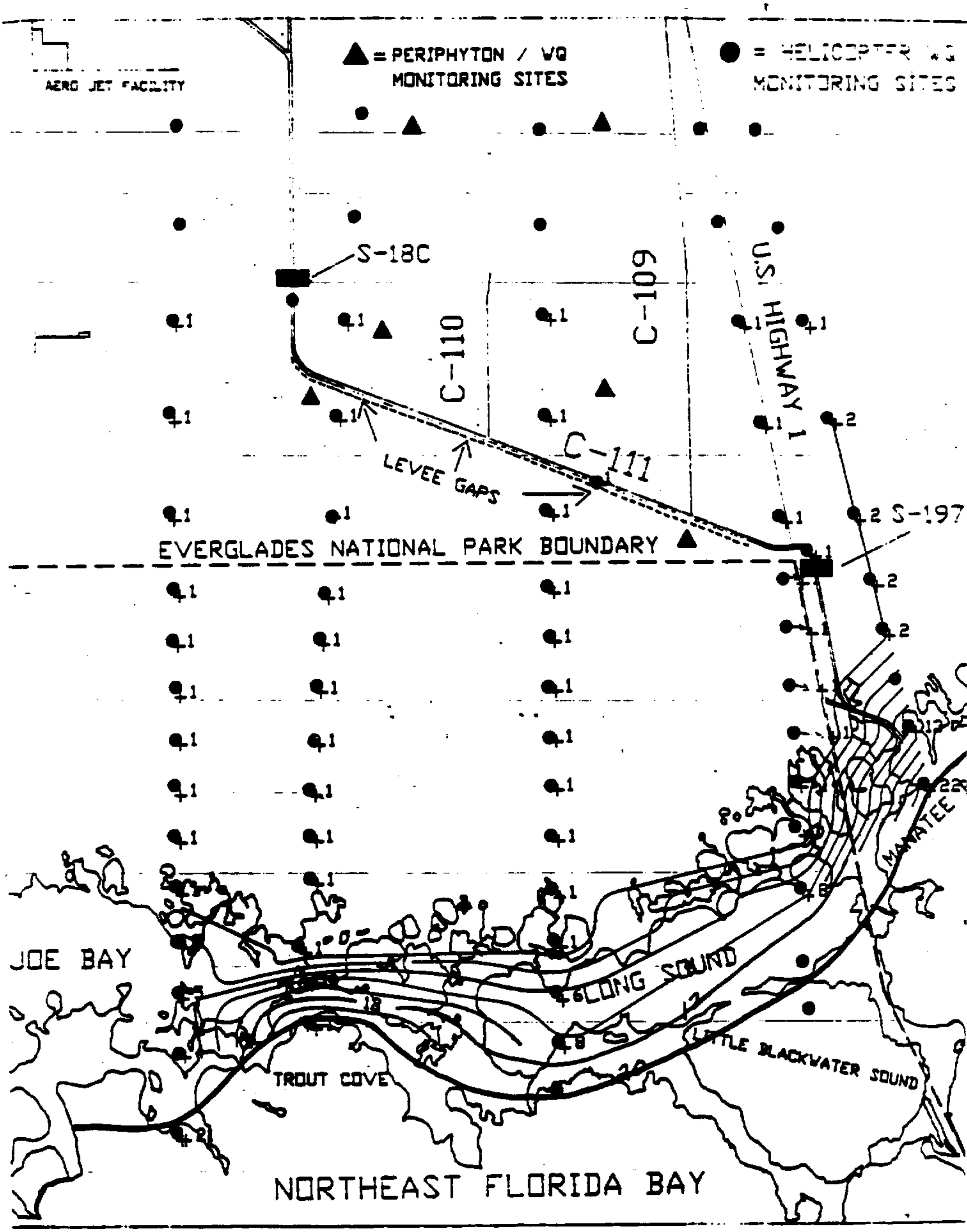
FIGURE 18. WET SEASON SALINITY (PPT) DATA, AUGUST 1985.



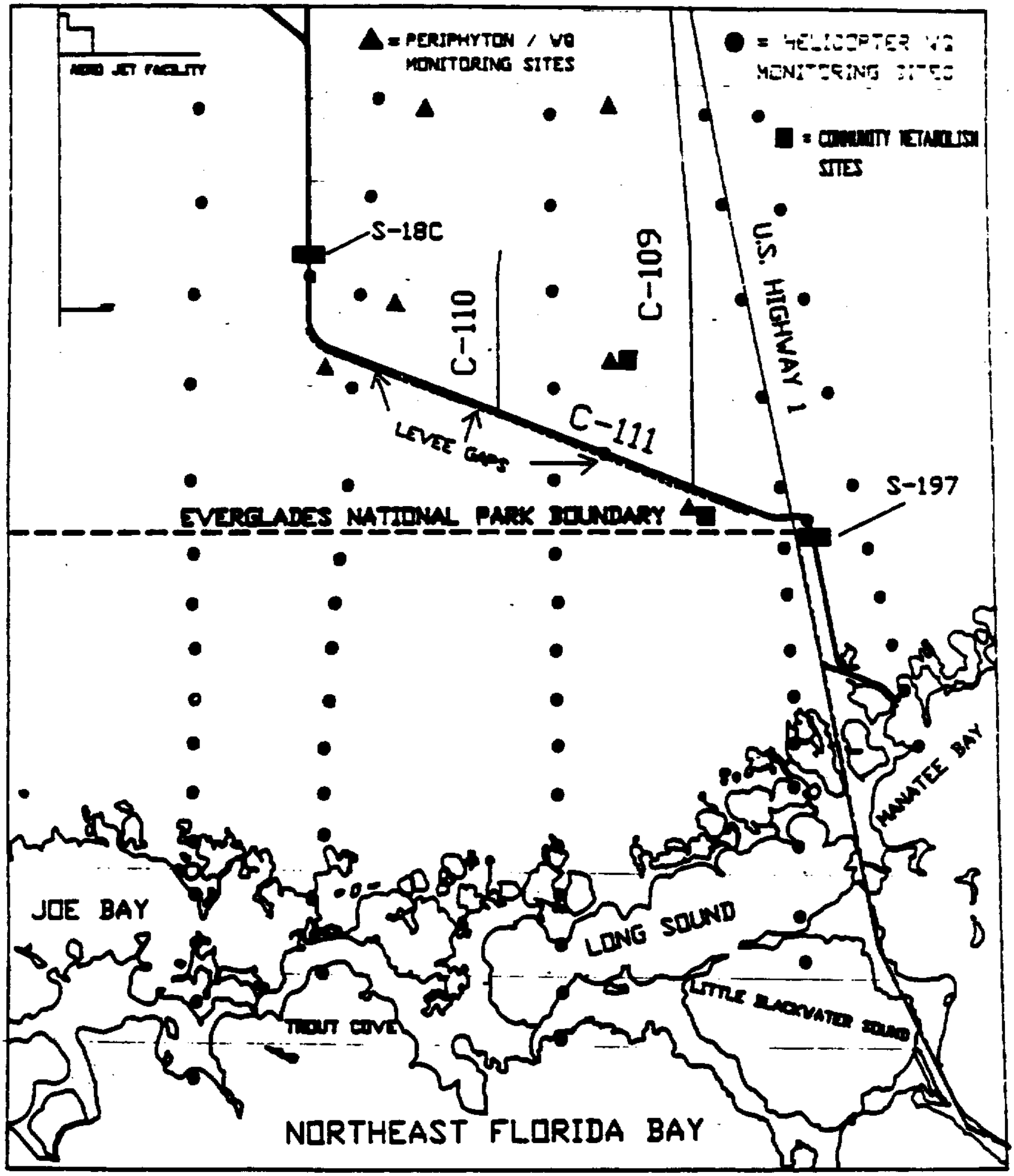
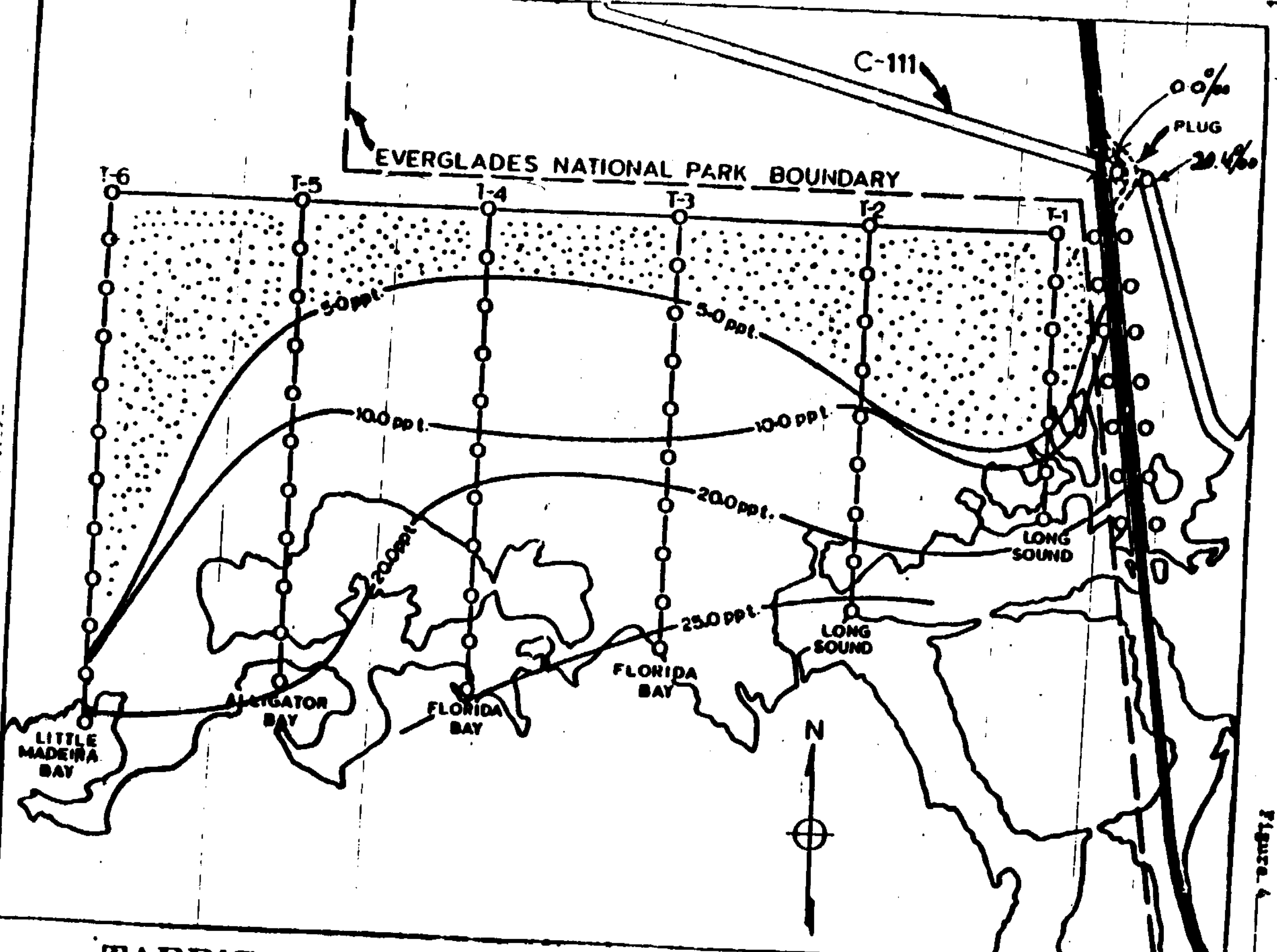



Figure 10: C-111 Study Area




TABB'S SALINITY DATA, FEB. 16—MAR. 10, 1967

FIGURE Ⅲ /13

TABLE 8 Comparison of S-18C Water Chemistry Data with Selected South Florida Canals which Drain Agricultural Lands

| | Total $PO_4$ (mg/l) | Ortho-$PO_4$ (mg/l) | Inorganic-N** (mg/l) | Total N (mg/l) | Conductivity (µmhos/cm) | pH | $CaCO_3$ Alkalinity (mg/l) | Ca (mg/l) | Cl (mg/l) | Years Sampled | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C-111 Canal (@S-18C) | .007* (.003) | .004 (.001) | .23 (.11) | 1.14 (0.30) | 585 (100) | 7.3 6.0-7.9 | 204 (16) | 73 (11) | 66 (30) | 10/83-08/86 | 57 |
| L-67A (@ S-151) | .023 (.021) | .006 (.009) | .21 (.28) | 2.33 (.80) | 873 (129) | 7.2 6.3-7.9 | 241 (38) | 75 (11) | 110 (26) | 12/77-2/85 | 132 |
| L-67A (@ S-333) | .016 (.012) | .004 (.007) | .15 (.26) | 2.22 (1.50) | 743 (123) | 7.3 6.7-7.7 | 210 (37) | 66 (10) | 87 (23) | 8/78-2/85 | 102 |
| Nutrient Enriched EAA Canal Water | | | | | | | | | | | |
| Miami Canal (@ S-8) | .102 (.124) | .046 (.074) | .96 (1.11) | 3.37 (1.86) | 786 (193) | 7.5 4.6-8.9 | 221 (74) | 84 (27) | 88 (29) | 4/73-8/86 | 380 |
| Hillsborough Canal (@ S-6) | .091 (.096) | .056 (.088) | 1.36 (1.50) | 4.45 (2.43) | 1327 (290) | 7.2 6.3-8.1 | 323 (85) | 93 (19) | 191 (42) | 6/74-8/86 | 370 |

*upper value = mean; lower value in parenthesis = standard deviation
**Inorganic-N = $NO_3 + NO_2 + NH_4$
Source: Water Chemistry Division, South Florida Water Management District

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# Correspondence/Notes

Sign IN - Nov. 29 Meeting C-111

| Name | Agency | Phone # |
| --- | --- | --- |
| Dewey Worth | SFWMD | 687-6605 |
| JOHN HASHTAK | COE - PLANNING | 904-791-2232 |
| MIKE CHOATE | COE - HYDROLOGY | 904-791-3143 |
| CAL NEIDRAUER | SFWMD | (407)686-5800 |
| Ron Bearzotti | SFWMD | " " |
| Lewis Hornung | Corps | 904-791-2585 |
| PAUL WHALEN | SFWMD | |
| Shawn Sculley | " | (407) 686-8800 |
| Jim Tilmant | NPS | (305)-245-5266 |
| BOB JOHNSON | NPS | " |
| WALT DINEEN | WMD | (407) 686-8800 x6601 |
| Mike Soukup | NPS/EVER | 305-245-5266 |
| TOM MACVICAR | SFWMD | 407 686 8800 |
| CARLOS ESPINOSA | DADE CO. DERM | 305-375-3375 |
| Wayne Richter | " | 305-375-3830 |
| Jon Moulding | COE | 904) 791-2286 |
| John C. Ogden | NPS | 305-245-5266 |
| DAVID FERRELL | USFWS | 407-562-3909 |
| ARNOLD BANNER | " | " |
| JOAN BROWDER | US NMFS | 305-361-4270 |
| HERB ZEBUTH | FDER | 407-464-9668 |
| Dan Dunford | FL Game & Fish Comm | 407-683-0748 |
| Susan Bellmund | SFWMD | 407-687-6716 |
| DAN HAUNERT | SFWMD | 407-687-6606 |

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Part B. March 21, 1990 Meeting

LETTER SENT TO ATTACHED DISTRIBUTION LIST.

*Protecting South Florida's Water Resources for 40 Years*
*1949-1989*

# South Florida Water Management District

P.O. Box 24680 • 3301 Gun Club Road • West Palm Beach, FL 33416-4680 • (407) 686-8800 • FL WATS 1-800-432-2045

February 22, 1990

Mr. Dan Dunford
Florida Game and Fresh
Water Fish Commission
551 North Military Trail
West Palm Beach, FL 33415

Dear Mr. ~~Dunford~~: Dan

This letter is a follow-up to our interagency meeting on the District's Interim C-111 Plan held November 29, 1989. At that meeting, District staff outlined the permit conditions issued by the Department of Environmental Regulation (DER) for the Interim C-111 Project. Conditions of the permit require the District to develop a monitoring program in cooperation with other regulatory agencies within six months after issuance of the construction permit (issued November 16, 1989). After approval by DER, the monitoring plan will be incorporated into the construction and operation permit for the Interim C-111 project.

A conceptual framework for the monitoring plan was discussed at the November interagency meeting. Based on these discussions, District staff have prepared a draft monitoring and operation plan. A copy of this document and supporting information is enclosed for your review. We would appreciate any written comments by March 16. An interagency meeting will be held at the District offices in West Palm Beach on March 21 to discuss any proposed changes to the draft monitoring and operation plan.

If you need further information, please contact Dewey Worth at (407) 687-6605.

Sincerely,

Tom MacVicar

Thomas K. MacVicar
Deputy Executive Director

TKM/DFW/tcs
Enclosure

bc: Dick Rogers
Jim Harvey
Tony Federico
Dewey Worth

A-4

# DISTRIBUTION LIST

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Mr. David Ferrell
U. S. Fish & Wildlife Service
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Everglades National Park
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Homestead, FL 33030

Mr. Bob Johnson
Everglades National Park
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Colonel Bruce A. Malson
U. S. Army Corps of Engineers
P. O. Box 4970
Jacksonville, FL 32232-0019

Mr. Mann Davis
U. S. Army Corps of Engineers
P. O. Box 4970
Jacksonville, FL 32232-0019

# South Florida Water Management District

P.O. Box 24680 • 3301 Gun Club Road • West Palm Beach, FL 33416-4680 • (407) 686-8800 • FL WATS 1-800-432-2045

March 15, 1990

bc: Tom MacVicar
Department Directors
Planning Department Division Directors
Jim Harvey
Ron Bearzotti, with attach.

Mr. Dan Dunford
Florida Game and Fresh
Water Fish Commission
551 North Military Trail
West Palm Beach, FL 33415

Dear Mr. Dunford:

The District has scheduled a meeting at our West Palm Beach office on March 21 at 1:30 p.m. in Conference Room "C" to discuss the C-111 Interim Monitoring and Operation Plan. An agenda is outlined below. Questions, comments and concerns will be discussed at this meeting. The District would also like to discuss a related proposal by the Fish and Wildlife Service (FWS) to modify C-111E (see enclosure). We would appreciate your agency's participation.

AGENDA
MARCH 21, 1990
C-111 INTERIM PLAN: OPERATION AND MONITORING

1:30 - Plan Overview

1:45 - Discussion on Comments/Proposed Modifications

3:00 - Consensus on Final Plan

3:30 - Review of FWS Proposal

If you have any questions, please contact me at (407) 687-6605.

Sincerely,

Dewey F. Worth

Dewey F. Worth
Supervising Professional
Environmental Planning Division
Planning Department

DFW/tcs
Enclosure

p. 48

# DISTRIBUTION LIST

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Water Fish Commission
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Department of Environmental
Regulation
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Mr. Herb Zebuth
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Mr. Ken Haddad
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Everglades National Park
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Homestead, FL 33030

Mr. Bob Johnson
Everglades National Park
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Homestead, FL 33033

Colonel Bruce A. Malson
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Jacksonville, FL 32232-0019

Mr. Mann Davis
U. S. Army Corps of Engineers
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Jacksonville, FL 32232-0019

Dr. Joan Browder
National Marine Fisheries Service
Southeast Fisheries Center
75 Virginia Beach Drive
Miami, FL 33149

Dr. Ron Hoffstetter
Department of Biology
University of Miami
P. O. Box 249118
Coral Gables, FL 33124

Mr. Eric Hughes
EPA Wetland Unit
345 Courtland Street, N.E.
Atlanta, GA 30342

A-C

Revised:

# AGENDA

## MARCH 21, 1990

## C-111 INTERIM PLAN; OPERATION AND MONITORING

1:30 - Plan Overview

* Addition of Taylor Slough Rainfall Plan
* Schedule

2:00 - Discussion on Comments/Proposed Modifications

3:00 - Consensus on Final Plan

3:30 - Review of FWS Proposal - Permit Considerations

A

| Name | Agency | Phone |
|---|---|---|
| Rick Alleman | Dade Cty-DERM | 305 375332 |
| JOHN R. ADAMS | SFWMD - HOMESTEAD | 305 248 142 |
| Sarah Bellmund | SFWMD -EPD | 4076876716 |
| Celia A. ROZAS | MDWASAD | (305) 665-7471 |
| HERB ZEBUTH | FDER | (407) 964-9668 |
| Jean Evoy | Dade Planning | 305-375-283 |
| ERIC MYERS | DADE CO. DERM | |
| Jim Tilmant | Everglades N.P. | 305-245-1381 |
| BOB JOHNSON | EVERGLADES N.P. | " |
| Arnold Banner | USFWS | 407 5623909 |
| RORY SANTANA | F.D.O.T | 305-470-5214 |
| LAURA BRINKLEY | FDOT | 305/470-5223 |

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C-111 MEETING 3/21/90

| NAME | AGENCY | POSITION |
|---|---|---|
| Ronald Mierau | SFWMD | DIRECTOR OPERA |
| George Henderson | DNR- Marine Research | Environmental H |
| Cal Neidrauer | SFWMD | Water Resources Eng |
| DAN HAUNERT | " | ENV. PLANNING |
| Robert Chamberlain | " | District Env Sci Di |
| Steve Carney | DOT/ CLARK ENGINEERS | Consultan |
| Shawn P. Sculley | SFWMD | Asst. Director, Water Res. D |
| Joan Browder | NOAA-NMFS | Ecosystem Team Leade |
| Ron Bearzotti | SFWMD | Construction Management D |
| Scott Thorp | SFWMD (513) | |

3-21-90

## C-111 Interim Monitoring and Operation Plan

### Interagency Meeting

Herb Zebuth did not think permit was so restrictive as to limit operational flexibility.

Arnold Banner concerned that no environmental goals set for Panhandle area.

Currently S-175HW @ 4.5 triggers opening of S-175. We propose 5.0' may not fly w/farmers.

S-176
Bob Johnson brought up part about not having gravity flow from L-31N south of S-331 thru S-174 to L-31W canal.

ENP hoping to raise S-176 NW.

Need to look more closely @ operational stages of SDCS particularly S-174, S-175, and S-176.

G-3439 - 3 miles east of Krome (2 yrs of data) may be useful and desire to include in monitoring network.
3272 gone 1/3 (NESRS-5 burned out).

USGS Study placed wells north of C-1W on either side of L-31N canal. Not published yet.

B. Johnson recommends a new gage in line of EVER-4 and EVER-3 between C-110 and C-109. (Help for eastern flowway (spreader canal) experiment too).

B.J. mentioned limited topo info south of ENP road.

Mierau indicated that 1 gage in (Fla Bay?) may be discontinued. Park said let them know if District wants to have them pick it up.

Salinity-discharge relationships - not decided who will develop these.

May 16 deadline for approved plan (by all agencies). Construction of S-197 and 6-211 done by August (!)

Dewey said internal memo written by Dan regarding 500 cfs estuarine impacts can be provided.

Dade Co. DERM (Eric Myers) asked about biological monitoring in NES (near Krome well also).

Herb wanted copy of COE permit.

Some discussion of how data would be summarized and transferred.

Frequency of interim progress reports needs to be determined.

Tillmont said he did not want to overburden District with data efforts.

3-21-90

S-18C flow meas problems discussed by Mierau and Johnson.

Arnold Banner wants to look @ modeling effort results for COE GDM (C-111) to evaluate TS RFP Art ES before he approves it.

Spreader Swale Proposal

DOT plans for US 1.

Approx. 20 culverts (1/2 are to 1/4 mi spacing N to S).

If a concensus is arrived at, DOT has no problems modifying their plans.

As long as it is done v. soon.

DOT looking at construction in 94?

DOT money issue - none allocated for 94-95 construction.

DOT's planning deadlines - Rouy Santana wants to implement agencies opinion but needs report before approx. '94 (not certain).

DOT calling culverts
equalizers

Dewey - within next 2 wks a document incorporating todays will be sent to all agencies for signature.

Goal: to DFER by May 1.

Part C. Written Comments

*Florida Department of Environmental Regulation*

**Southeast District** • 1900 S. Congress Ave., Suite A • West Palm Beach, Florida 33406 • 407-964-9668

Bob Martinez, Governor | Dale Twachtmann, Secretary | John Shearer, Assistant Secretary
Scott Benyon, Deputy Assistant Secretary

March 30, 1990

Mr. Dewey F. Worth
South Florida Water Management District
Post Office Box 24680
West Palm Beach, Florida 33416-4680

Dear Mr. ~~Worth~~, DEWEY

I have completed my review of the Interim Monitoring and Operation Plan for the C-111 Basin. It had become separated from the remaining material after being received in this office. I found it on the 22nd.; sorry for the delay.

Specific Condition 5. of Permit No. 131654749 for the interim C-111 Plan which required the interagency coordination also established purposes for that coordination. They included "to fully identify and discuss all issues related to the operation and monitoring of the improved S-197, develop criteria under which discharges will be performed, develop appropriate monitoring criteria to assess impacts of discharge from the structure and a schedule for implementation." While the area of monitoring criteria has been generally documented, the areas of discharge criteria and implementation schedule require additional information. Regrettably, full identification and discussion of all issues related to the S-197 has been severely restricted.

One important area of monitoring in need of improvement is the coordination and incorporation of hydrology data with water quality and biological data and studies. Some past studies have referred to various environmental conditions in the study areas without adequately linking these conditions with C-111 or S-197 discharges, area rainfall or other factors. This should be one of the primary objectives of future monitoring and environmental investigations. What comparisons have you made using past S-197 discharge data and DERM quarterly epifloral and epifaunal data? The water quality results section of one study (Attachment 7.) contained the statement, "Results from monitoring special discharge events from S-197 are available upon request." This is one of our major concerns. All such data should be provided to the interagency group.

Flood control operating criteria have been provided for most structures in the C-111 basin. It would be beneficial to also

A.5

have information on the normal operating criteria for these structures as well as details on any agreements which affect their operations. Several references to 'the agreement with the farmers on operation of the system' were made by SFWMD personnel and ENP personnel at the March 21st. meeting. This agreement has been mentioned numerous times during the last several years. Please provide details of this agreement to group members.

Are the wet and dry season flood control stages for S-176 correct as listed on Page 10 of the Operating Plan? It has been suggested that these have been reversed. No operating criteria have been provided for S-174. How is it used to reduce flood conditions at S-176? How are S-174, S-175 and S-332 used in flood control efforts? How are they used to reduce the need to make harmful discharges through S-197? How can their usefulness be increased? What criteria controls the opening of only 1 or 2 culverts at S-197?

According to the flood criteria provided, S-177 will be opened when its headwater elevation reaches 4.0 feet (NGVD). A rise of only 0.1 feet to 4.1 ft. at S-177 will trigger the opening of 3 culverts at S-197. A 0.2 ft. rise to 4.2 will trigger the opening of 7 culverts. Opening 7 culverts is equivalent to partially removing the old plug at S-197. Previously, culvert discharge and plug removal were postponed until the stage reached 4.3 ft. The proposed lower stage opening of the culverts may divert additional and/or possibly unnecessary water away from the panhandle of ENP with the potential of unnecessary adverse effects on Manatee Bay.

Even if opening 3 culverts at a lower stage reduces the need to open more culverts later, substantial amounts of fresh water could still be lost. During 1986, 28,945 acre feet of fresh water were discharged through the 3 culverts without the need to remove the plug. During the single month of August 1986, 17,830 acre feet were discharged through the existing 3 culverts. For 1987, 23,351 acre feet of fresh water passed through the 3 culverts to Manatee Bay. In 1988, the total amount of fresh water discharged to Manatee Bay increased to over 101,000 acre feet. Of this amount, about 60,000 acre feet were discharged through the existing 3 culverts. According to SFWMD estimates, with the interim project in place, about 38,500 acre feet of fresh water would have been discharged to Manatee Bay during 1988.

With the project in place, the predicted flow during the August 1988 event would have been "reduced" to 16,800 acre feet. This volume of fresh water would cover a five and one quarter square mile area to a depth of five feet. The total surface area of Manatee Bay is less than five and one quarter square miles and it has an average depth of less than five feet. Such an event would still be devastating. Such large scale, occasional discharges of fresh water are the most damaging to estuarine systems. Since no salinity model exists for Manatee Bay and Barnes Sound, no information exists on the volume of freshwater those estuaries can tolerate. This information is needed.

In addition to the environmental destruction, consideration must be given to the simple waste of large volumes of fresh water. If put into terms most people understand, fresh water discharges to Manatee Bay through S-197 amounted to about 9.5 billion gallons during 1986, 7.6 billion gallons during 1987 and 33.0 billion gallons during 1988. With the project in place, the deliberate loss of fresh water during 1988 would still have been over 12.5 billion gallons. Ironically, several months later during 1989, water restrictions were imposed on southeast Florida because of a severe drought!

We have mentally separated construction of facilities to more efficiently discharge fresh water to the ocean from our search for environmentally acceptable locations for new well fields and our need for new water supplies. Instead of treating excess water during wet years as a curse, it should be recognized as a valuable resource and a much greater effort made to store that water in upstream locations. Upland storage areas (the Bird Drive Basin, the Frog Pond, etc.) as well as aquifer storage and recovery systems should be investigated. Water saved in such locations could later be slowly released to natural areas as needed, used for wellfield recharge or to irrigate agricultural land. Water resources in south Florida are limited and competition between agriculture, urban areas and the environment will increase. The environment has few options. A major focus of any SFWMD or COE project should be conservation not discharge of our water resources.

Implementation of a rainfall driven water delivery plan for Taylor Slough appears to offer a potential improvement over present operations. A major question which remains unresolved is the ability of the proposed model "to provide water supply and environmental benefit to Everglades National Park (ENP) - that existed prior to the alteration of the slough hydrology that resulted from construction of the Central and Southern Florida Project." Material supplied by Mr. Bob Johnson of ENP indicates the proposed model was developed using flow data from a period of record already affected by project development. Mr. Johnson's period of record appears to be a more valid base period. After modifying the model to incorporate Mr. Johnson's data, it would be helpful to have information on the monthly volumes of water supplied so a comparison can be made with the current minimum delivery schedule. Another very useful and important bit of information would be documentation of the effect the L-31W Canal has on water flow after delivery to Taylor Slough.

Limitations on the scope of our group discussions have restricted a full examination of the issues resulting from the operation of the C-111 Canal and the S-197 structure. A number of questions from several group members have received the answer, "That will be addressed in the Corps C-111 GDM." Such an answer fails to recognize that many of the agencies have been excluded from participation in the Corps' current GDM development process. It also fails to recognize the potential for opposition to the final Corps C-111 GDM or the possibility the project may not be funded or constructed. A free and open discussion should occur so group consensus on C-111 issues can be incorporated into the Corps process or if necessary, into the Everglades SWIM process.

A major issue in these discussions should be the mitigation of environmental impacts which will be associated with the operation of the interim project. Areas of discussion should include removing canal water to reestablish sheet flow, storage of water for a slow, more natural release to natural systems, and the addition of pumps at critical gravity flow locations to reduce the need for S-197 discharges. Although the U.S. Fish And Wildlife Service suggestion for a spreader canal to distribute water over the marsh east of the C-111 was presented to the group, the assertion that it was outside the permit requirement reduced discussion, consideration and commitment. A full identification and discussion of all issues related to the operation of the S-197 remains to be completed.

Sincerely,

Herbert H. Zebuth

Herbert H. Zebuth
Environmental Coordinator

cc: Interagency group members
Donald White
Larry O'Donnell
John Bossart

# MEMORANDUM

| | | | |
|---|---|---|---|
| TO: | Eric Myers<br>Biol. Resources Section | DATE: | March 16, 1990 |
| FROM: | Dennis Howard<br>Agricultural Waste Section | SUBJECT: | Pesticides Monitored in SFWMD Canal Program |

The list of pesticides analyzed in the SFWMD canal monitoring program is relatively comprehensive, however, several compounds commonly applied to one or more crops grown in the C-111 basin are missing. Suggested additions (in decreasing order of priority) are as follows:

Atrazine- The SFWMD has been analyzing for (and detecting) residues of this herbicide. Perhaps it was inadvertantly deleted from the list you were given?]

Maneb/Mancozeb- Heavily applied on several row crops. Can degrade to ethylene thiourea, a suspected carcinogen.

Ethylene Thiourea- Degradation product of maneb and other ethylene bis-dithiocarbamate pesticides. Potential carcinogen.

Butylate- Potential leacher, commonly used on corn

Acephate- Commonly used on several crops

Dimethoate- Occasionally used on many crops

Metalaxyl- Commonly used on squash

Diquat- Commonly used on tomatoes

Dade DERM request to expand water Quality monitoring on C-111 to include the following parameters

DW.

Appendix 3. Rainfall Delivery Plan for Taylor Slough.

# THE TAYLOR SLOUGH RAINFALL PLAN

South Florida Water Management District
January 1990

## I. Introduction

The South Florida Water Management District (District) has developed a water management plan for Taylor Slough similar to the Rainfall Plan for Shark River Slough. The primary goal of the proposed Taylor Slough Rainfall Plan, as is the primary goal of the Shark River Slough Rainfall Plan, is to provide water supply and environmental benefit to Everglades National Park (Park) by restoring the more natural rainfall runoff response of Taylor Slough. Water deliveries to Taylor Slough are presently made via the S-332 pump station according to the Congressionally authorized Minimum Delivery Schedule. The proposed plan is considered to be a more rational approach to water management for Taylor Slough than the Minimum Delivery Schedule, and can be tested under PL 91-181, the program of experimental water deliveries to Everglades National Park.

Flow to Taylor Slough under the proposed plan will be in response to rainfall conditions in the area. During times of below normal rainfall, the plan will call for less than normal flow to the slough - thereby minimizing the competition for water supply with the urban coastal areas. Similarly, during times of above normal rainfall, the plan will call for more than normal flow to the slough - flow that has previously been discharged to the coast.

The discharge capacity of S-332 must be increased by about 80 cfs during the peak months of the wet season to achieve the flows prescribed by the plan. The District proposes to achieve this via a portable pump.

The purpose of this report is to document the Taylor Slough Rainfall Plan by reviewing some of the events leading to its development, the technical details of its development, and the structural modifications necessary to implement the plan.

## II. Background

In 1970 Congress established PL 91-282 to guarantee minimum water deliveries to the Park and to authorize construction of the necessary conveyance facilities. Delivery schedules were established that required minimum monthly deliveries to three areas of the Park (Figure 1): (1) Shark River Slough (SRS), (2) Taylor Slough (TS), and (3) the eastern panhandle of the Park. Flows to SRS were made via the S-12's. The South Dade Conveyance System (SDCS) was constructed to provide the conveyance facilities necessary to achieve the minimum deliveries to Taylor Slough and the eastern panhandle.

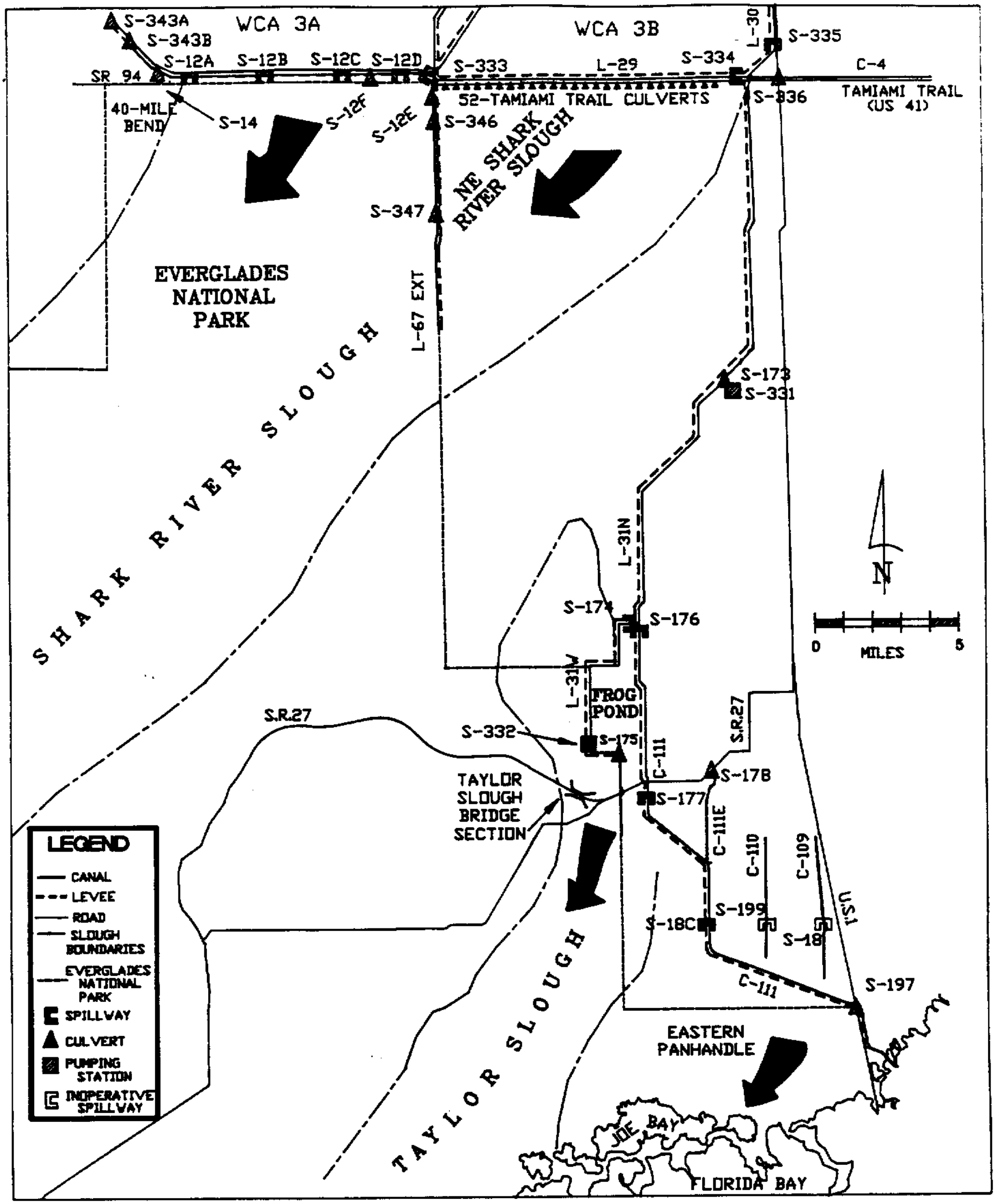


**Figure 1. Site Features**

The present means for delivering flow to Taylor Slough is the S-332 pump station which was constructed as part of the SDCS. S-332 became operational in late 1980 and pumps according to its monthly minimum delivery schedule. According to Wagner and Rosendahl's 1987 draft report History and Development of Water Delivery Schedules for Everglades National Park through 1982: the minimum delivery schedule for Taylor Slough was developed by Dunn in 1961 using less than one year of discharge data at Taylor Slough near Homestead (Taylor Slough Bridge flow section). This schedule called for an annual delivery of 37,000 acre feet. Monthly minimum deliveries set in 1970 (PL 91-282) were amended in 1976 via the "Agreement and Permit for Construction and Operation of Taylor Slough Pump Station S-332". No record of the analyses leading to the amended schedule could be found, however, personal communication with parties to the negotiations indicated that the new schedule took into account updated records for the Taylor Slough flow section and professional opinion regarding probable effects of S-332 pumpages on downstream flow.

The minimum delivery schedule for Taylor Slough that has been in effect since 1980 is summarized in Table 1 and is shown in Figure 2. Note the similarity between the minimum delivery schedule and the average (1961-70) flow at the Taylor Slough Bridge flow section. It is likely that the minimum delivery schedule was based on the 1961-70 flow data.

Table 1. Taylor Slough Minimum Delivery Schedule (1980-present)

| Month | Monthly Flow Volume [ac-ft] | Average Flow Rate [cfs] |
|---|---|---|
| Jan | 740 | 12.0 |
| Feb | 370 | 6.7 |
| Mar | 185 | 3.0 |
| Apr | 185 | 3.1 |
| May | 370 | 6.0 |
| Jun | 6,660 | 112.0 |
| Jul | 7,400 | 120.0 |
| Aug | 2,960 | 48.0 |
| Sep | 5,920 | 100.0 |
| Oct | 7,770 | 126.0 |
| Nov | 3,700 | 62.0 |
| Dec | 740 | 12.0 |
| Total | 37,000 | |

As data and knowledge accumulated during the 1970's, it became clear that the minimum delivery schedules did not provide the natural amount and timing of flow to the Park. The major weakness of the minimum delivery schedule is that flows are made according to the calendar and not according to the natural rainfall-runoff response. The minimum delivery schedule ignores both the inter- and intra- annual variability of rainfall.

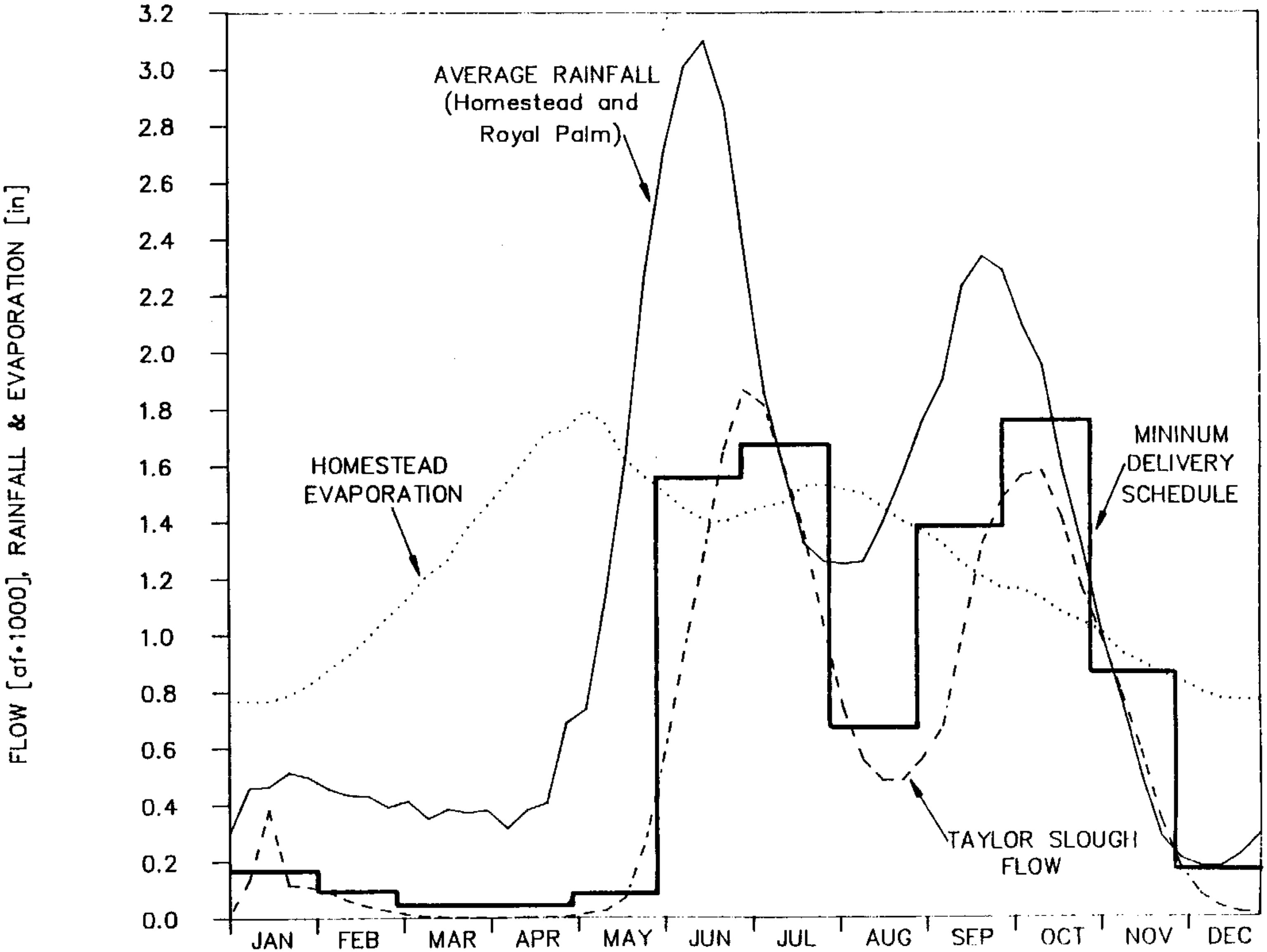


**Figure 2. Taylor Slough Minimum Delivery Schedule and 1961-70 Weekly Means**

In 1983, Congress passed PL98-181, the program of experimental water deliveries to the Park. This legislation allowed the District, Corps of Engineers (Corps), and Park to temporarily set aside the minimum delivery schedules to test alternative water management plans.

In July of 1985, the SRS Rainfall Plan was implemented under the experimental water delivery program, and it remains in effect pending the outcome of the Corps General Design Memorandum (GDM) for SRS.

The other minimum delivery schedules, Taylor Slough and the eastern panhandle schedules, have been in effect since 1981 and until recently attention has been focused on restoring more natural flows to SRS only.

## III. Taylor Slough Rainfall Plan

The Taylor Slough Rainfall Plan is a water management plan for determining the amount and timing of surface water flow to Taylor Slough. The goal of the plan is to provide water supply and environmental benefit to Everglades National Park by restoring the rainfall-runoff response of the slough that existed prior to the alteration of the slough hydrology that resulted from construction of the Central and Southern Florida Project.

For the proposed Taylor Slough Rainfall Plan, weekly flow at S-332 is determined by the sum of two components: (1) a Rain-Driven component, and (2) a Supplemental component; both components are determined by statistical models and are discussed in detail on the following pages. The Rain-Driven component is based on flow data at the Taylor Slough Bridge section and local rainfall data; whereas the Supplemental component accounts for surface water losses which are known to occur between S-332 and the bridge section.

### A. Rainfall Formula

The Rain-Driven component of the Taylor Slough Rainfall Plan is determined by a statistical model referred to as the Rainfall Formula. The Rainfall Formula predicts flow in Taylor Slough where it crosses US 27 (hereinafter referred to as the Taylor Slough Bridge flow section) from the average of rainfall at the Homestead Experiment Station and the Royal Palm Ranger Station.

The period of data used to develop the Rainfall Formula was from 1961 through 1970. This 10-year period was the earliest record of daily flow in Taylor Slough and was assumed to be representative of the natural flow response to rainfall. Construction of L-31W in 1971 affected the rainfall-runoff response of the slough as is shown by the double mass curve (Figure 3). Note the decrease in slope in 1971. Also note from Figure 3 that the rainfall-runoff response was altered again in 1980 when S-332 became operational and the minimum delivery schedule for Taylor Slough was implemented. As a result of the minimum delivery schedule, the slope of the relationship increased to about the same as it was during the 1961-70 period. Thus, the minimum delivery schedule helped to restore the annual flow volume to the slough; but, the fixed monthly schedule does not restore the inter- or intra-annual flow response to rainfall.

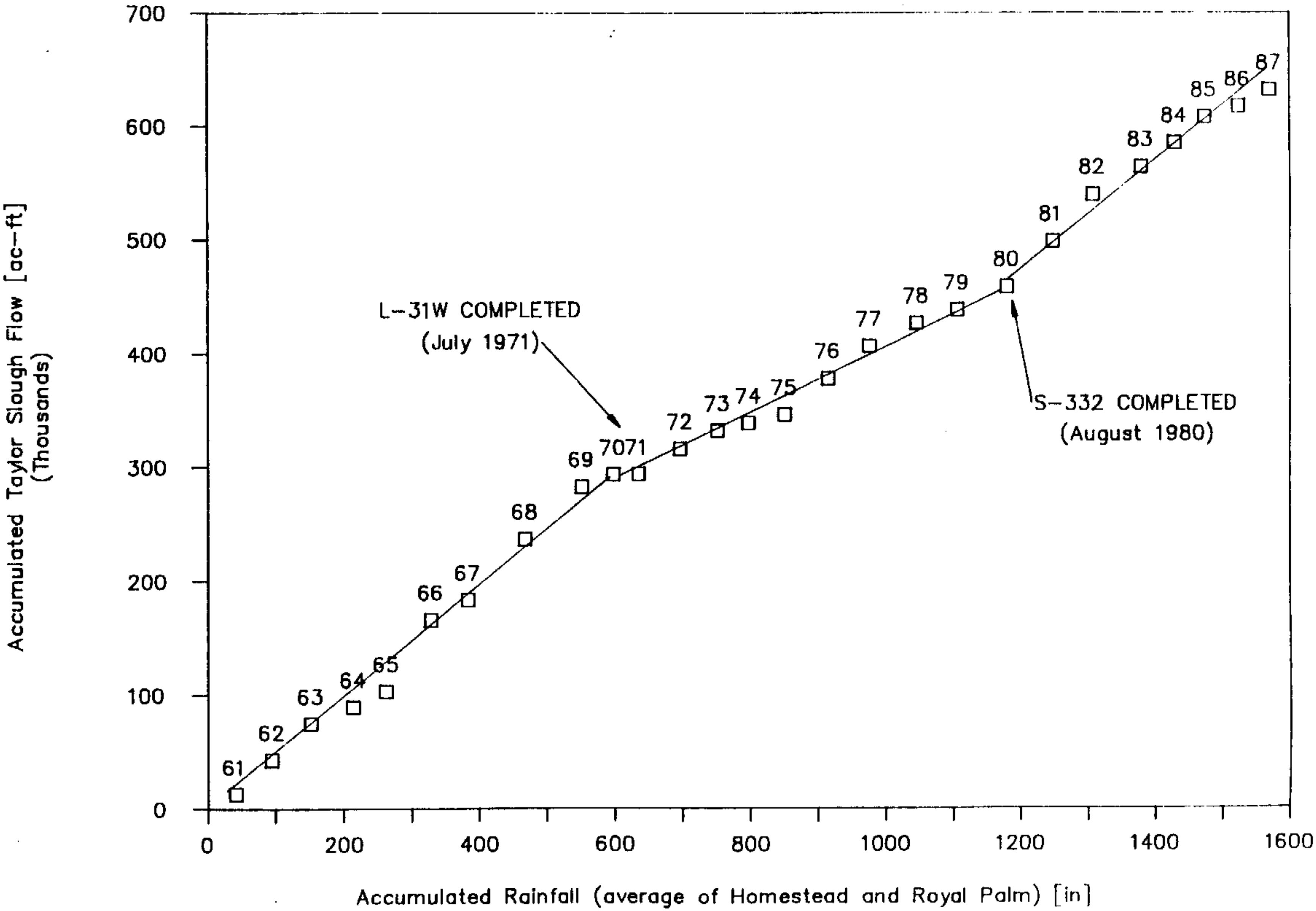


**Figure 3. Double Mass Curv- 'llustrating Changes in Taylor Slough**

## 1. Data Preparation

Rainfall, evaporation, and flow data were processed by the following methodology:

a. Rainfall and evaporation data at the Homestead Experiment Station, rainfall data at the Royal Palm Ranger Station, and flow data at Taylor Slough near Homestead (flow through the Taylor Slough Bridge and the culverts under US 27 along a 3-mile flow section) were retrieved from the SFWMD database DBHYDRO (station names HOMES.ES, ROYAL PA, and TAYLORS2). This data was summed in weekly time steps. February 29 and December 31 were omitted in order to produce fifty-two seven-day periods per year, each starting with January 1. There was no missing flow data or rainfall data at Homestead, only a few days of missing rainfall data at Royal Palm, but the Homestead evaporation data had occasional missing daily values and three long periods of missing data: (1) 70 days from 3/3/61 to 5/11/61, (2) 249 days from 1/1/63 to 9/6/63, and (3) 608 days from 5/3/69 to 12/31/70. Occasional missing evaporation values of one to two days were estimated via linear interpolation.

b. Five-week centered moving averages were computed for the rainfall, evaporation and flow data. From these moving averages, weekly means and standard deviations were calculated (Figure 2 and Table 2). The weekly mean evaporation was used for the three periods of missing evaporation data. Rainfall at Royal Palm and Homestead were similar in amount and distribution (Table 3). An arithmetic average of rainfall at these two sites was considered representative of the rainfall conditions in the slough headwaters.
c. The weekly flow, rainfall, and evaporation data were de-seasonalized and standardized by subtracting the weekly means and dividing by the weekly standard deviations.

$$ZQ' = (Q' - Q'mean)/Q'stddev$$
$$ZR = (R - Rmean)/Rstddev$$
$$ZE = (E - Emean)/Estddev$$

Where

ZQ' is the standardized weekly flow;
Q' is the observed weekly discharge [acre feet];
Q'mean is the 1961-70 weekly mean discharge [acre feet];
Q'stddev is the 1961-70 weekly flow standard deviation [ac-ft];
ZR is the standardized weekly rainfall;
R is the observed weekly rainfall [inches];
Rmean is the 1961-70 weekly mean rainfall [inches];
Rstddev is the 1961-70 weekly rainfall standard deviation [in];
ZE is the standardized weekly evaporation;
E is the observed weekly evaporation [inches];
Emean is the 1961-70 weekly mean evaporation [inches]; and
Estddev is the 1961-70 weekly evaporation standard deviation [in].



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Table 2. Weekly Flow, Rainfall, and Evaporation Summary Statistics (determined from 1961-1970 data)+

| Week No. | Weekly Flow Rate Mean(cfs) | StdDev | Average* Rainfall Mean(in) | StdDev | Pan Evaporation Mean(in) | StdDev |
|---|---|---|---|---|---|---|
| 1 | 9.74 | 29.79 | 0.46 | 0.25 | 0.76 | 0.06 |
| 2 | 9.17 | 27.57 | 0.46 | 0.27 | 0.77 | 0.06 |
| 3 | 8.47 | 25.08 | 0.52 | 0.34 | 0.79 | 0.05 |
| 4 | 7.89 | 23.12 | 0.50 | 0.25 | 0.82 | 0.04 |
| 5 | 6.69 | 19.28 | 0.46 | 0.31 | 0.88 | 0.08 |
| 6 | 4.39 | 12.35 | 0.44 | 0.14 | 0.93 | 0.07 |
| 7 | 2.88 | 8.37 | 0.43 | 0.15 | 0.99 | 0.07 |
| 8 | 1.84 | 5.44 | 0.39 | 0.14 | 1.06 | 0.07 |
| 9 | 0.87 | 2.59 | 0.41 | 0.16 | 1.13 | 0.07 |
| 10 | 0.31 | 0.96 | 0.35 | 0.18 | 1.21 | 0.05 |
| 11 | 0.13 | 0.42 | 0.39 | 0.19 | 1.26 | 0.10 |
| 12 | 0.07 | 0.21 | 0.37 | 0.24 | 1.38 | 0.12 |
| 13 | 0.03 | 0.10 | 0.38 | 0.29 | 1.46 | 0.17 |
| 14 | 0.00 | 0.01 | 0.32 | 0.27 | 1.54 | 0.16 |
| 15 | 0.00 | 0.01 | 0.38 | 0.36 | 1.63 | 0.18 |
| 16 | 0.04 | 0.12 | 0.41 | 0.37 | 1.72 | 0.17 |
| 17 | 0.26 | 0.67 | 0.69 | 0.72 | 1.72 | 0.19 |
| 18 | 1.08 | 2.94 | 0.74 | 0.73 | 1.80 | 0.18 |
| 19 | 1.87 | 5.28 | 1.13 | 0.96 | 1.75 | 0.21 |
| 20 | 5.08 | 12.85 | 1.61 | 1.17 | 1.62 | 0.25 |
| 21 | 19.00 | 27.06 | 2.26 | 1.33 | 1.56 | 0.22 |
| 22 | 42.06 | 48.17 | 2.71 | 0.98 | 1.51 | 0.16 |
| 23 | 68.63 | 65.32 | 3.01 | 1.14 | 1.45 | 0.15 |
| 24 | 92.76 | 83.35 | 3.10 | 1.18 | 1.41 | 0.14 |
| 25 | 119.53 | 103.75 | 2.87 | 1.28 | 1.40 | 0.16 |
| 26 | 134.22 | 113.26 | 2.36 | 1.23 | 1.43 | 0.14 |
| 27 | 130.52 | 112.47 | 1.86 | 0.80 | 1.45 | 0.13 |
| 28 | 115.13 | 112.74 | 1.58 | 0.65 | 1.47 | 0.13 |
| 29 | 98.45 | 109.99 | 1.32 | 0.45 | 1.53 | 0.12 |
| 30 | 74.36 | 93.99 | 1.26 | 0.54 | 1.53 | 0.13 |
| 31 | 52.97 | 74.73 | 1.25 | 0.47 | 1.51 | 0.10 |
| 32 | 39.94 | 57.33 | 1.26 | 0.40 | 1.50 | 0.05 |
| 33 | 34.66 | 45.24 | 1.40 | 0.48 | 1.45 | 0.09 |
| 34 | 34.97 | 42.51 | 1.56 | 0.63 | 1.40 | 0.08 |
| 35 | 40.61 | 41.62 | 1.76 | 0.67 | 1.37 | 0.06 |
| 36 | 48.68 | 43.07 | 1.90 | 0.69 | 1.32 | 0.09 |
| 37 | 72.23 | 64.28 | 2.23 | 0.75 | 1.25 | 0.12 |
| 38 | 95.36 | 88.06 | 2.34 | 0.72 | 1.21 | 0.10 |
| 39 | 106.71 | 100.97 | 2.29 | 0.62 | 1.16 | 0.10 |
| 40 | 112.62 | 107.59 | 2.10 | 0.72 | 1.16 | 0.12 |
| 41 | 113.75 | 109.93 | 1.95 | 0.80 | 1.13 | 0.09 |
| 42 | 101.68 | 83.93 | 1.59 | 0.68 | 1.08 | 0.09 |
| 43 | 84.17 | 63.42 | 1.31 | 0.57 | 1.05 | 0.09 |
| 44 | 71.57 | 58.44 | 1.01 | 0.56 | 1.01 | 0.08 |
| 45 | 57.24 | 49.69 | 0.77 | 0.45 | 0.94 | 0.08 |
| 46 | 42.33 | 39.14 | 0.50 | 0.28 | 0.90 | 0.10 |
| 47 | 24.86 | 22.38 | 0.29 | 0.18 | 0.86 | 0.09 |
| 48 | 12.86 | 12.08 | 0.21 | 0.18 | 0.84 | 0.08 |
| 49 | 5.70 | 6.25 | 0.18 | 0.16 | 0.80 | 0.08 |
| 50 | 2.60 | 3.45 | 0.18 | 0.19 | 0.77 | 0.07 |
| 51 | 1.09 | 1.78 | 0.22 | 0.13 | 0.77 | 0.07 |
| 52 | 0.56 | 1.01 | 0.30 | 0.19 | 0.77 | 0.05 |
| TOTAL | 29333 acre feet | | 59.75 inches | | 64.16 inches | |

+ statistics based on five-week centered moving averages
* average of rainfall at Homestead and Royal Palm

Table 3. Annual Rainfall and Flow Totals (1961-87)

| Year | Homestead Rainfall (inches) | Royal Palm Rainfall (inches) | Average Rainfall (inches) | Taylor Slough Actual Flow (acre feet) | Taylor Slough Predicted Flow (acre feet) |
|---|---|---|---|---|---|
| 1961 | 45.8 | 36.5 | 41.1 | 13059 | 19871 |
| 1962 | 55.6 | 51.2 | 53.4 | 30076 | 29617 |
| 1963 | 62.2 | 52.6 | 57.4 | 32006 | 32630 |
| 1964 | 61.1 | 62.8 | 61.9 | 14355 | 29973 |
| 1965 | 46.3 | 49.9 | 48.1 | 13892 | 22875 |
| 1966 | 59.8 | 73.0 | 66.4 | 62593 | 28012 |
| 1967 | 54.2 | 56.0 | 55.1 | 17125 | 25013 |
| 1968 | 83.6 | 85.3 | 84.4 | 53720 | 43331 |
| 1969 | 83.8 | 83.8 | 83.8 | 45835 | 42155 |
| 1970 | 45.9 | 46.1 | 46.0 | 10573 | 20416 |
| 1971 | 37.0 | 37.3 | 37.1 | 675 | 16370 |
| 1972 | 64.0 | 59.7 | 61.8 | 22276 | 31053 |
| 1973 | 57.9 | 53.1 | 55.5 | 15670 | 30903 |
| 1974 | 43.4 | 47.7 | 45.6 | 6880 | 26015 |
| 1975 | 51.4 | 53.2 | 52.3 | 7438 | 27516 |
| 1976 | 71.6 | 57.7 | 64.6 | 32188 | 33320 |
| 1977 | 63.3 | 58.1 | 60.7 | 28335 | 31499 |
| 1978 | 64.8 | 74.3 | 69.6 | 20198 | 34867 |
| 1979 | 66.8 | 54.5 | 60.6 | 11496 | 29745 |
| 1980 | 75.5 | 73.0 | 74.3 | 20457 | 38412 |
| 1981 | 74.7 | 60.7 | 67.7 | 40019 | 42891 |
| 1982 | 56.1 | 63.8 | 60.0 | 41118 | 27703 |
| 1983 | 71.1 | 73.1 | 72.1 | 24198 | 32141 |
| 1984 | 53.8 | 46.4 | 50.1 | 21043 | 27928 |
| 1985 | 41.0 | 46.6 | 43.8 | 22733 | 20077 |
| 1986 | 53.3 | 47.1 | 50.2 | 9134 | 22267 |
| 1987 | 49.8 | 43.4 | 46.6 | 14476 | 23793 |
| AVERAGES | | | | | |
| 1961-70 | 59.8 | 59.7 | 59.8 | 29323 | 29389 |
| 1971-80 | 59.6 | 56.8 | 58.2 | 16561 | 29970 |
| 1981-87 | 59.4 | 56.8 | 58.1 | 24147 | 29401 |



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## 2. Model Selection and Parameter Estimation

Several forms of a multiple regression equation were devised and evaluated. The goal of this evaluation was to determine the regression equation that produced the optimum rainfall formula. That is, a rainfall formula that maximized the goodness of fit to the observed flow data, and minimized the number of independent terms. Results of this evaluation showed that neither rainfall terms lagged more than six weeks or evaporation significantly improve the predictive ability of the formula. The lagged discharge term, ZQpred(t-1) did not significantly improve the goodness of fit, but was included since it produced a smoother appearing hydrograph and reduced the magnitude of the negative flows. Thus, the final formula depends only on the preceding six week's rainfall and the flow predicted for the previous week.

$$ZQ_{RF}(t) = CQ \cdot ZQ_{RF}(t-1) + \sum_{i=1}^{3} \{CR_i \cdot \sum_{j=2i-1}^{2i} ZR(t-j)\} \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where

| | |
|---|---|
| $ZQ_{RF}(t)$ | $= \{Q_{RF}(t) - \text{Qmean}(t)\}/\text{Qstddev}(t)$ |
| $ZR(t-j)$ | $= \{R(t-j) - \text{Rmean}(t-j)\}/\text{Rstddev}(t-j)$ |
| t | = time step index [weeks] |
| $Q_{RF}(t)$ | = predicted weekly discharge rate [cfs] |
| Qmean(t) | = 1961-70 weekly mean discharge [cfs] |
| | = Q'mean[acft] / 1.9835[acft/cfsday] / 7[days/week] |
| Qstddev(t) | = 1961-70 weekly flow standard deviation [cfs] |
| | = Q'stddev[acft] / 1.9835[acft/cfsday] / 7[days/week] |
| R(t-j) | = lagged weekly rainfall (avg. of Homestead & Royal Palm)[in] |
| Rmean(t-j) | = lagged 1961-70 weekly mean rainfall [in] |
| Rstddev(t-j) | = lagged 1961-70 weekly rainfall standard deviation [in] |

The coefficients **CQ**, $\mathbf{CR_1}$, $\mathbf{CR_2}$, and $\mathbf{CR_3}$ of Equation 1 were estimated via least squares regression. The regression coefficients and the bounds on the 95 percent confidence interval (C.I.) are shown in Table 4.

Table 4. Regression Coefficients [dimensionless]

| | LOWER LIMIT 95% C.I. | REGRESSION COEFFICIENT | UPPER LIMIT 95% C.I. |
|---|---|---|---|
| CQ | 0.6020 | 0.6638 | 0.7256 |
| $CR_1$ | 0.0410 | 0.0561 | 0.0712 |
| $CR_2$ | -0.0030 | 0.0120 | 0.0271 |
| $CR_3$ | -0.0001 | 0.0138 | 0.0277 |

## 3. Goodness of Fit

Figure 4 illustrates the time series of the historic flow and the flow predicted by the rainfall formula (Equation 1). This figure was prepared to graphically demonstrate the goodness of fit of the rainfall formula for the period used to derive the formula coefficients (1961-70).

In general, the rainfall formula under-predicts the high flows and reasonably predicts the low and intermediate flows. Note that the formula predicts some small negative flow at times. These negative flows are just an artifact of most curve fitting methods and should be interpreted as zero flows.

The basic summary statistics (mean, standard deviation, and skewness) of the actual and predicted flow are presented in Table 5 below. Note that the negative flows were set equal to zero before the statistics were computed. In general, the statistics of the predicted flow should be similar to those of the historic flow in order to achieve a "good fit".

Table 5. Summary Statistics

| | **Historic Flow** | **Predicted Flow** |
|---|---|---|
| Weekly Mean [cfs] | 40.2 | 41.2 |
| Standard Deviation [cfs] | 82.5 | 54.1 |
| Skewness | 3.03 | 1.42 |

Standard Error of the Estimate [cfs] = 54.5

The mean is probably the most important statistic to preserve since it is directly related to the amount of water that flows to the slough. Table 5 shows that the mean of the predicted flow is nearly the same as the mean of the historic flow.

The standard deviation is a measure of the average variability of the flow. The standard deviation of the flow predicted by the formula is 28.4 cfs (34 percent) lower than that of the historic flow. The standard deviation of the predicted flows is lower because the formula tends to under-predict the highs of the historic flow distribution. Thus, the flow predicted by the formula is less variable than the historic flow.

The skewness is a measure of the symmetry of the distribution of flows. A zero skewness corresponds to a distribution of flows that is symmetric around its mean (e.g., the normal distribution has zero skewness). A distribution of flows having zero skewness has about the same amount of low flow as high flow. A positive skewness corresponds to a distribution of flow that includes many low flows and relatively fewer high flows; this is typical of flow distributions. A flow distribution having negative skewness is unusual. The skewness of the flow predicted by the formula was positive, but lower than that of the historic flow. Thus, the distribution of the predicted flow is more symmetric than the distribution of historic flow.

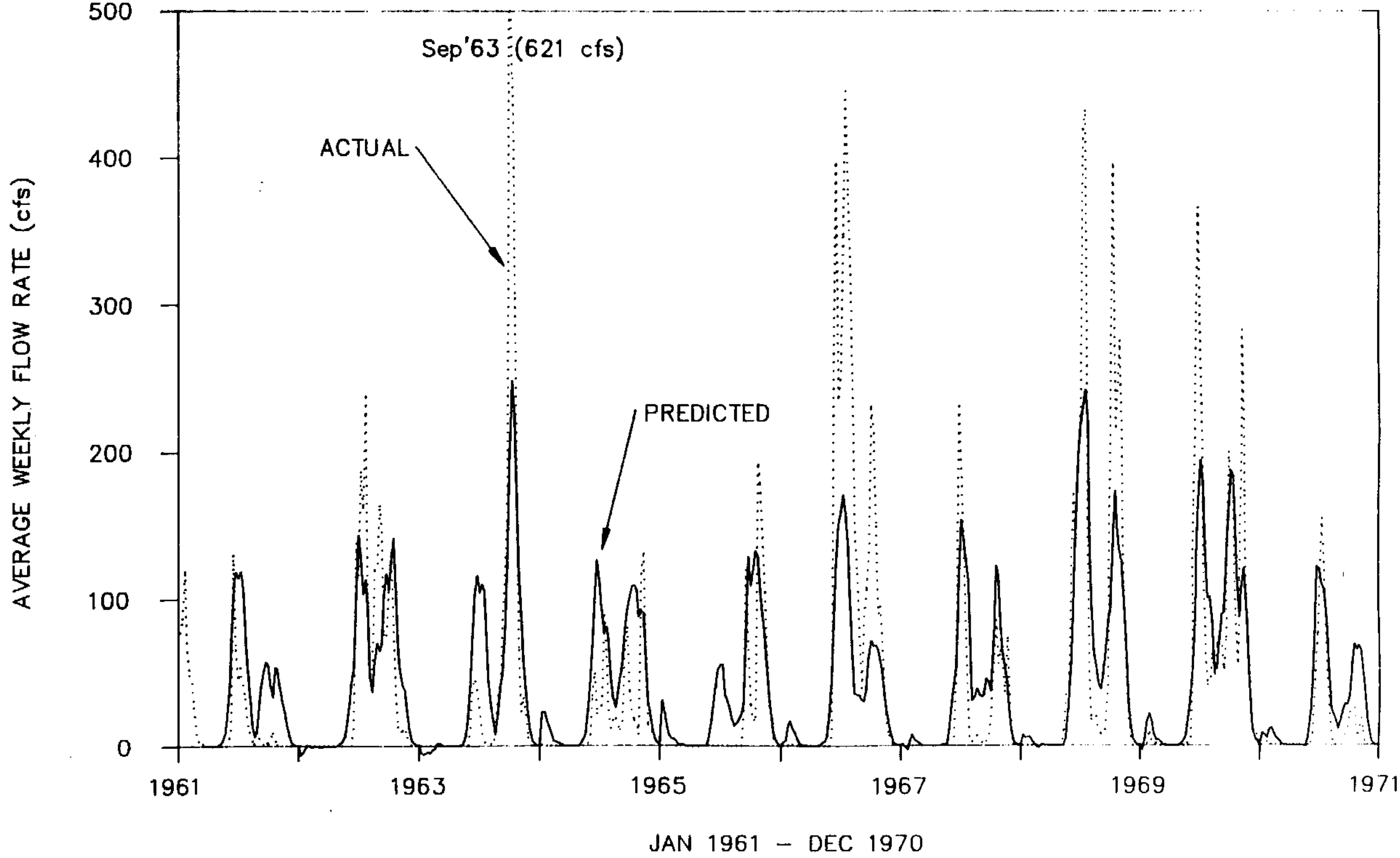


**Figure 4. Taylor Slough Flow: Actual and Predicted During the 1960's**

The standard error of the estimate gives an indication of the average variation in the historic flows that is not explained by the formula. It is desirable to minimize the value of this statistic and least squares regression does this. Slightly smaller values of the standard error were obtained by adding evaporation and/or more lagged rainfall terms to the formula; however, the small improvement was not enough to justify including the additional terms.

## 4. Simulation of the Taylor Slough Rainfall Formula (1971-1989)

Figures 5 and 6 show a comparison of the flow predicted by the rainfall formula (Equation 1) with the flow measured at the Taylor Slough Bridge section for the period 1971 to 1987. The predicted flow can be viewed as the flow that would have been measured at the bridge section had the 1960's rainfall-runoff response of the slough existed during 1971 to 1987.

The predicted flow was determined by the following procedure: Weekly rainfall at Homestead and Royal Palm were used to estimate the spatial average rainfall for the basin (observed weekly rainfall). The observed weekly rainfall values were then standardized by (1) subtracting the 1961-70 weekly mean rainfall and by (2) dividing the difference by the 1961-70 weekly rainfall standard deviation. The standardized rainfall was then used with Equation 1 to compute the standardized weekly flow rate. Finally, the standardized weekly flow rate was converted to the predicted flow rate by (1) multiplying the standardized weekly flow rate by the 1961-70 weekly flow standard deviation, and (2) subtracting the 1961-70 weekly mean flow rate.

Some differences between the actual and predicted flows are apparent. These are expected since the rainfall-runoff response was altered in 1970. During most of the years in the 1970's the predicted flow exceeded the historic flow; and during the 1980's, the predicted flow was similar in amount.

Figure 7 and Table 3 compare annual totals of the historic and flow predicted by the rainfall formula. Note that the predicted flow during the 1971-80 period is significantly higher than the historic flow. Table 3 shows the average annual predicted flow during this period was 13,400 acre feet higher than the actual average annual flow. Since the formula preserves most of the 1961-70 rainfall-runoff response, the lower historic flow during the 1970's is evident and is likely due to the drainage induced by the construction of L-31W. Table 3 also shows that the average annual predicted flow during the 1981-87 period was about 5,200 acre feet higher than the actual flow.

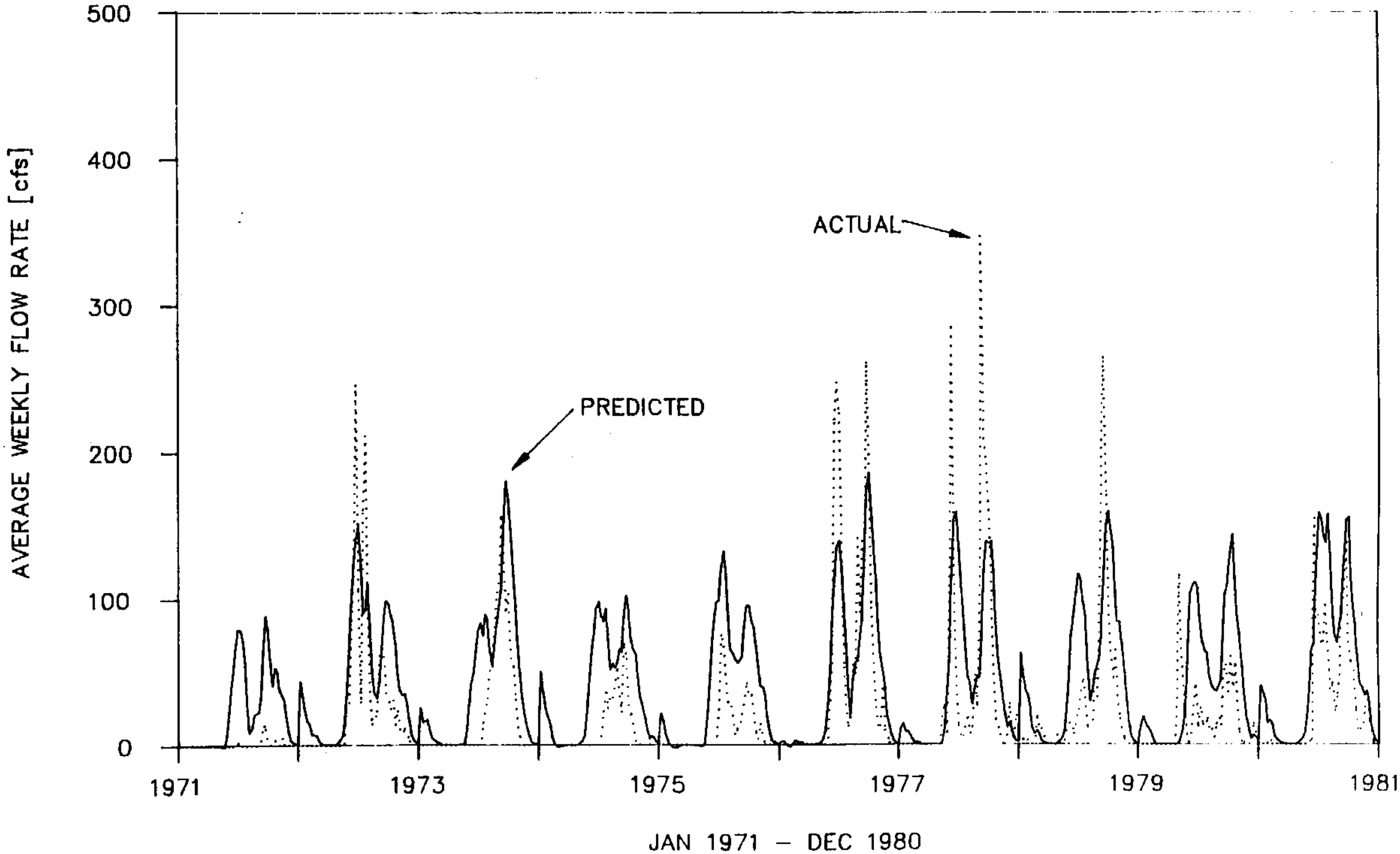


**Figure 5. Taylor Slough Flow: Actual and Predicted During the 1970's**

7-7

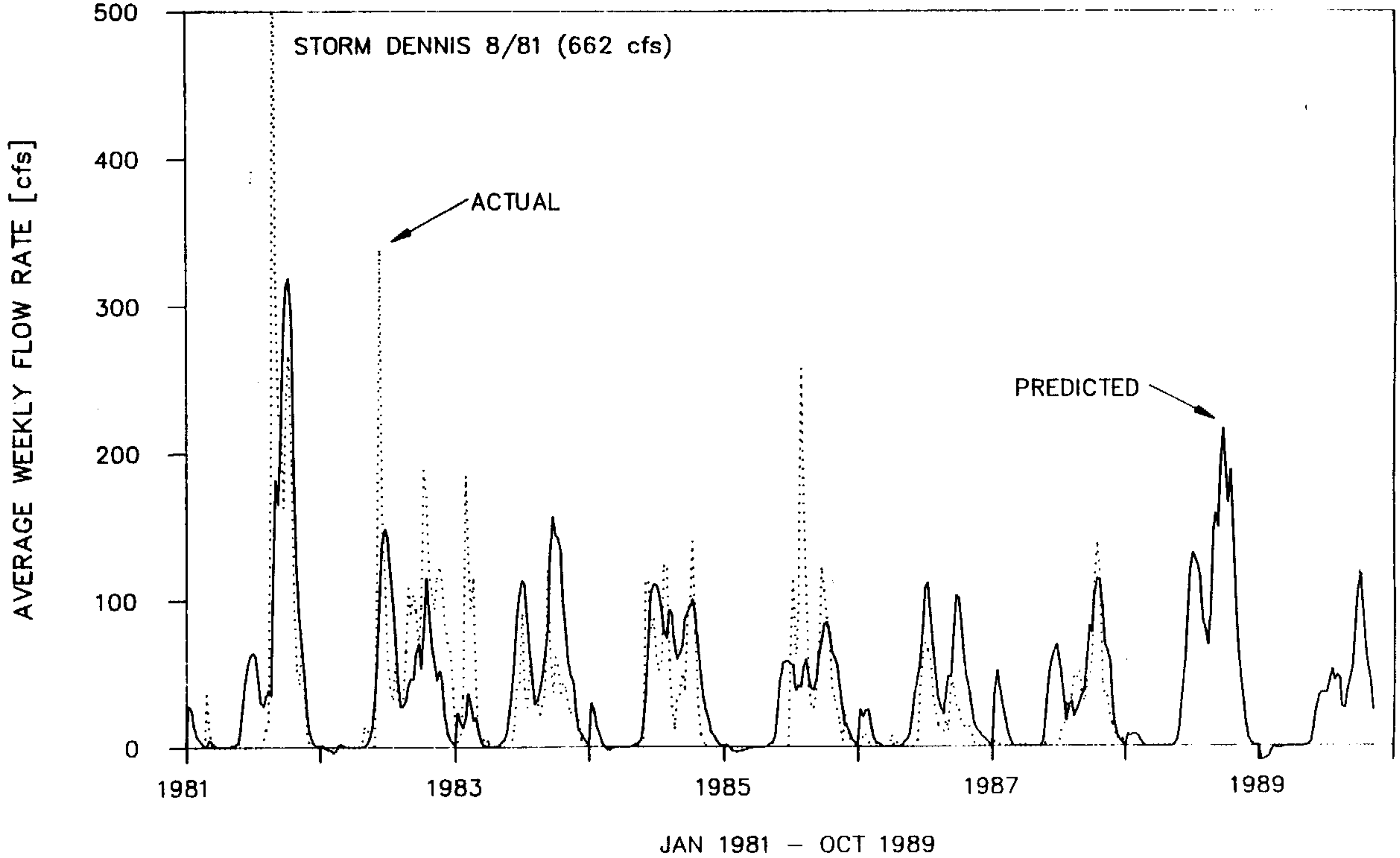


Figure 6 Taylor Slough Flow: Actual and Predicted During the 1980's

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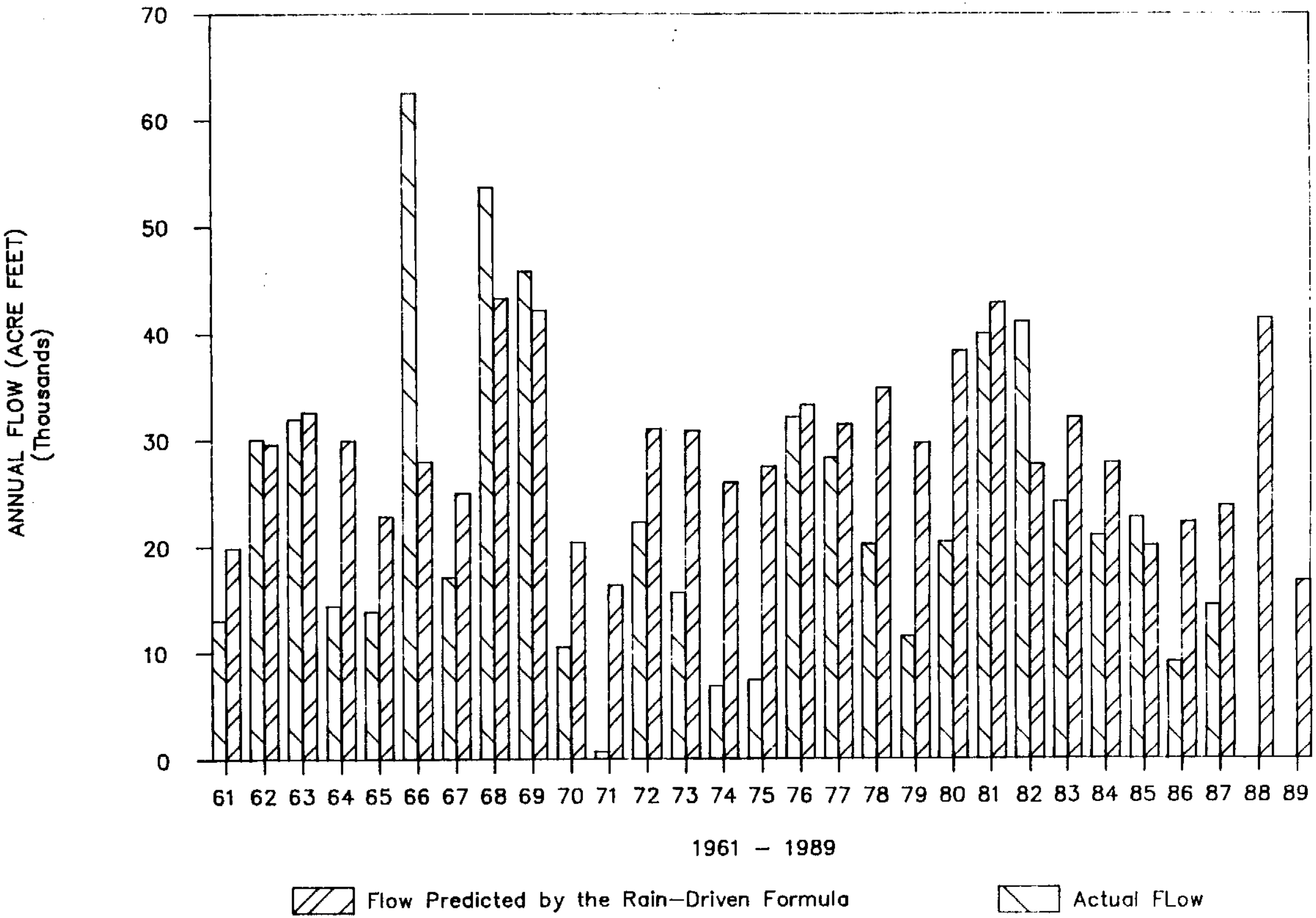



**Figure 7. Annual Taylor Slough Flow: Actual and Predicted**

## B. Supplemental Component

Discharge records collected since the S-332 pump came on line in 1980 indicate that the S-332 pumpage has usually exceeded the surface flow at the Taylor Slough Bridge section (Figures 8 and 9). This indicates that some of the water pumped at S-332 has not made it to the bridge section. The difference can be considered surface water lost to evapotranspiration and seepage and it was relatively large during 1986 and 1987.

The amount of this "lost surface water" depends primarily on the water level in the L-31W canal and water levels in the slough. These water levels provide an indicator of the available ground storage in the slough as well as an implicit indicator of the gradient driving flow back into the L-31W canal.

In order to achieve the rainfall formula amount at the bridge section, a supplemental discharge must be added to the rainfall formula amount. The supplemental discharge is determined by the following multiple linear regression equation:

$$Q_{SUP}(t) = 89.64 \cdot TW_{S332}(t-1) - 40.08 \cdot HW_{S332}(t-1) - 228.4 \quad [\text{cfs}] \quad . \; . \; . \; . \; (2)$$

$r^2 = .63$
Standard Error = 22.4 cfs

where

$Q_{SUP}(t) = Q_{S332}(t) - Q_{BRIDGE}(t)$
$Q_{S332}(t)$ = average weekly S-332 pump rate [cfs]
$Q_{BRIDGE}(t)$ = average flow rate at Taylor Slough Bridge section [cfs]
$TW_{S332}(t-1)$ = previous week's average S-332 tailwater stage [ft]
$HW_{S332}(t-1)$ = previous week's average S-332 headwater stage [ft]

The regression coefficients in Equation 2 were determined by least squares and the data set used to compute them was subject to the following constraints:

1. Weekly flows from January 1, 1981 to December 30, 1987 {available data}.
2. S-332 discharge > 0 {supplemental component not needed if pump is off}.
3. Consider only wet season data (June-December) {amount of "lost" surface water during the dry seasons was relatively small}.
4. $(Q_{S332} - Q_{BRIDGE}) > 0$ {desire to predict only positive supplemental discharge component}

Figure 10 shows a comparison of the supplemental discharge predicted by Equation 2 with the actual data (S-332 flow minus the flow at the bridge section) over the period 1980 to 1987. Note that the "goodness of fit" appears reasonable.

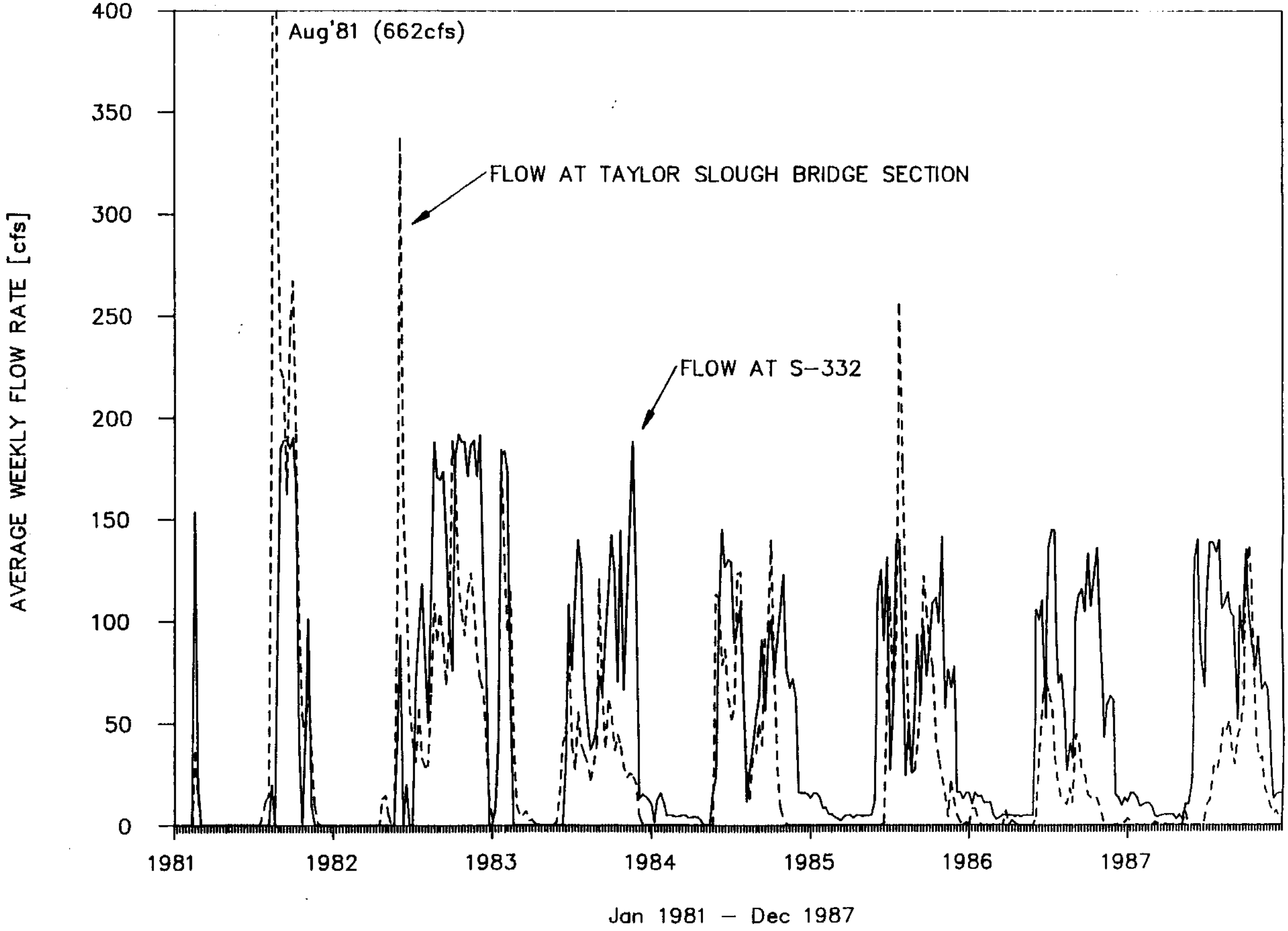



**Figure 8. Comparison of Week' Flow at the Taylor Slough Bridge Section with S-332 Flow**

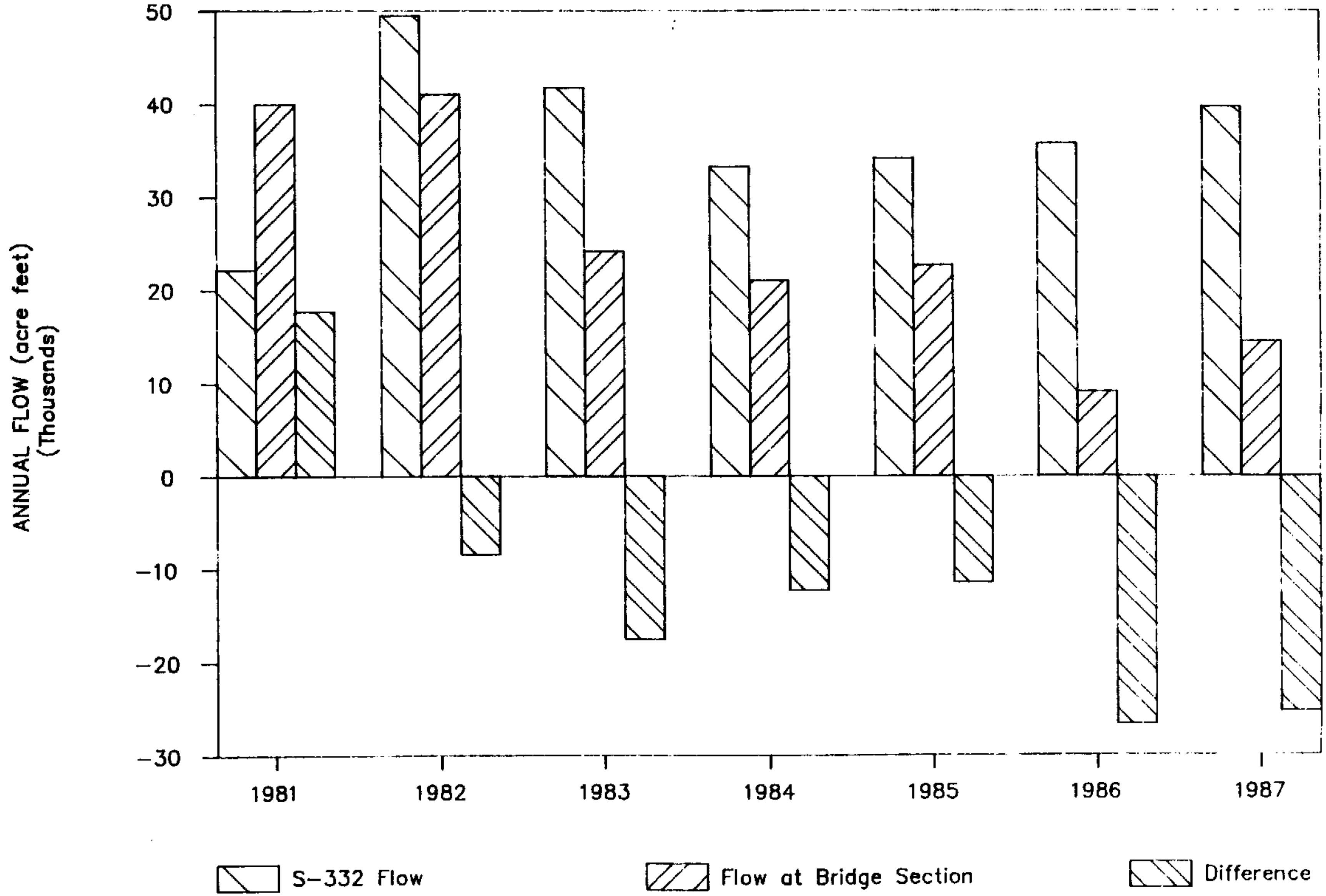



**Figure 9. Comparison of Annual Flow Volumes at the Taylor Slough Bridge Section with S-332 Flow**

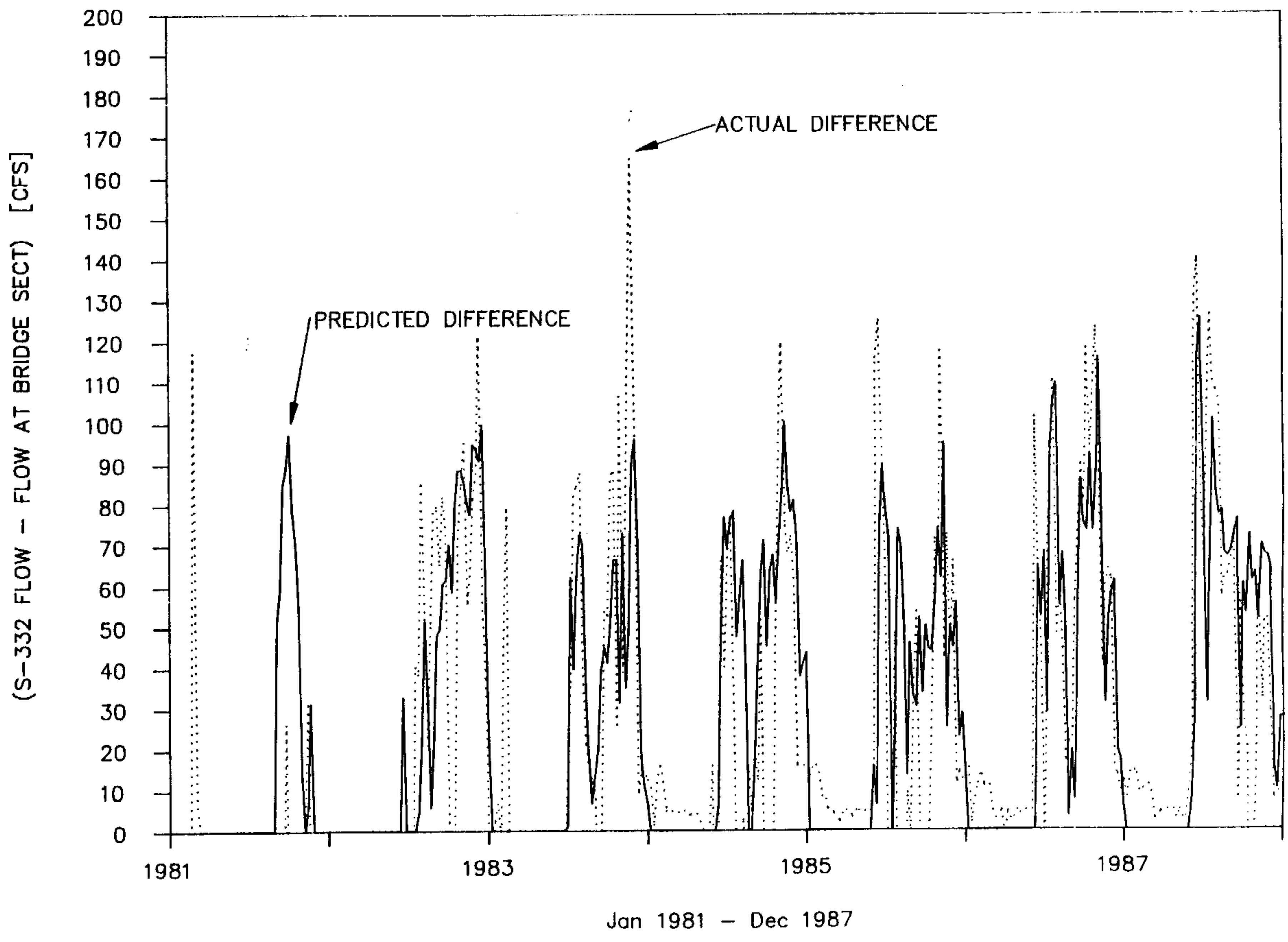



**Figure 10. Supplemental Discha: Component: Actual and Predicted**

## C. Flow at S-332 Prescribed by the Taylor Slough Rainfall Plan

Under the proposed Rainfall Plan for Taylor Slough, discharge at S-332 are determined by the sum of the rain-driven component (rainfall formula amount from Equation 1) and the supplementary component (Equation 2).

$$Q_{S332}(t) = Q_{RF}(t) + Q_{SUP}(t) \quad [\text{cfs}] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where $Q_{RF}(t)$ is the discharge prescribed by the rain-driven formula; and $Q_{SUP}(t)$ is the supplemental discharge that is expected to be "lost" to groundwater and evapotranspiration over the 9000 ft reach of the slough from S-332 to the Taylor Slough Bridge section. The supplemental flow is necessary to achieve the rain-driven discharge at the bridge section.

## D. Water Availability

Figure 11 shows a comparison of the weekly flow predicted by the Taylor Slough Rainfall Plan (sum of rain-driven and supplemental components) with the sum of the flow at S-174 and S-176. This comparison was made to assess whether enough water would have flowed through the South Dade Conveyance System during the period 1981-87 to make the deliveries to Taylor Slough had the Rainfall Plan been in effect. Note that the actual S-332 headwater and tailwater data were used to compute an estimate of the supplemental component.

From Figure 11 it can be seen that there has been sufficient water entering the C-111 basin during the 1981-89 period to provide the proposed deliveries to Taylor Slough. However, it is important to note that flow into the C-111 basin increased in 1983 as a result of the use of S-331 to provide increased flood protection to the 8.5 square mile residential area west of L-31N. Future changes to the Project that are proposed by the Shark River Slough GDM, C-111 Interim Project, and the west Dade wellfield may reduce the canal flow that will enter the C-111 basin. The quantity of water that will be available after these changes are made is not presently known, however the South Dade Conveyance System must maintain its designed ability to make deliveries to the Park.

Figure 12 shows a comparison of the flow predicted by the Taylor Slough Rainfall Plan with the minimum delivery schedule during 1988 (a wet year) and 1989 (a dry year). Rainfall in the area during 1988 was 70 inches, 12 inches above the 58 inch normal. During 1989, rainfall in the area was about 38 inches, 20 inches below normal.

During times of below normal rainfall, the Taylor Slough Rainfall Plan will call for less water to be delivered to the slough than is presently made via the minimum delivery schedule. This will lessen the competition for water supply with the coastal urban areas. And during times of above normal rainfall, the plan will call for more water than is presently delivered to the slough, water that has previously been discharged to Biscayne Bay and Florida Bay.

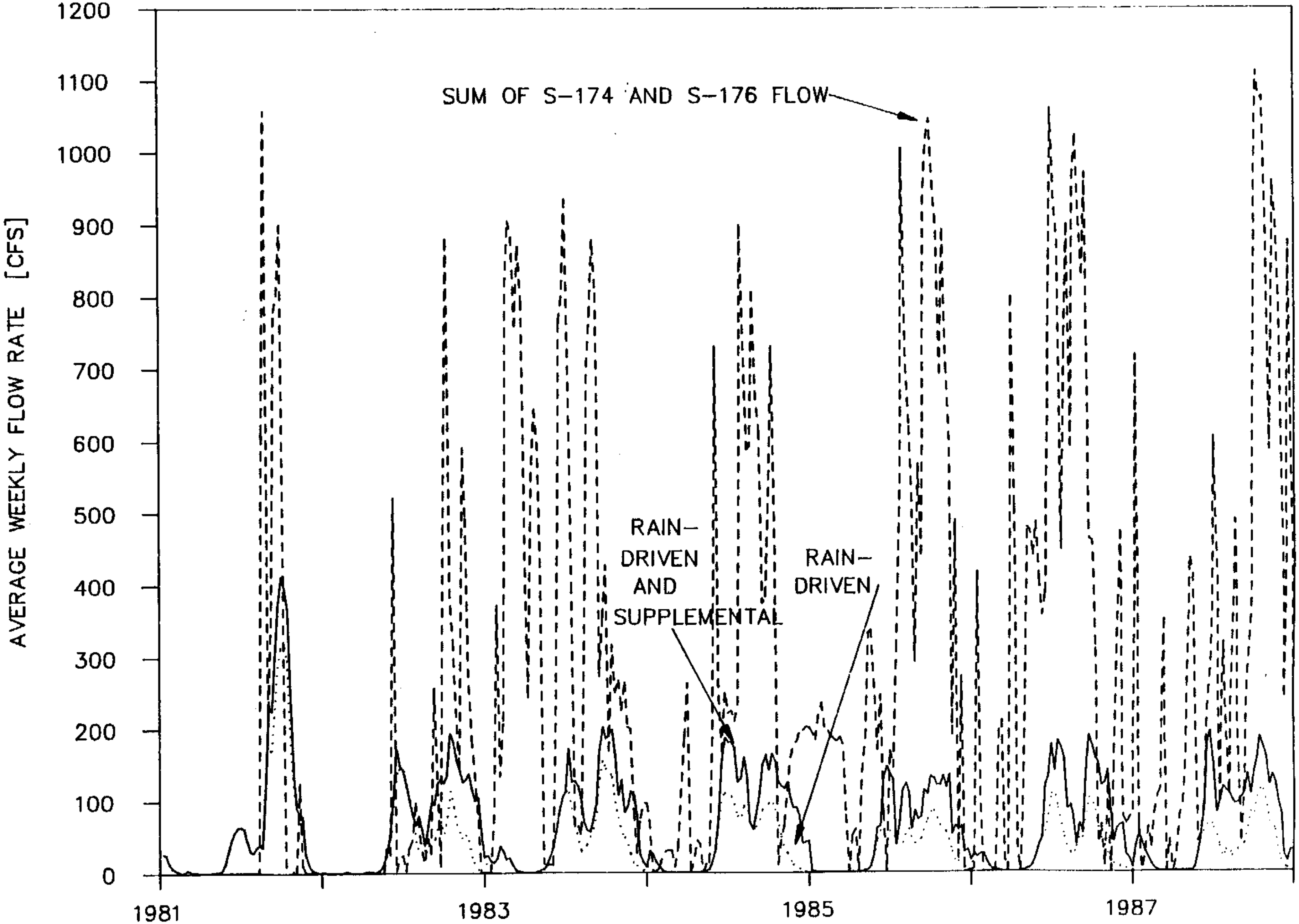



**Figure 11. Comparison of Rain-Driven and Supplemental Components with the Sum of S-174 and S-176 Flow**

B-5

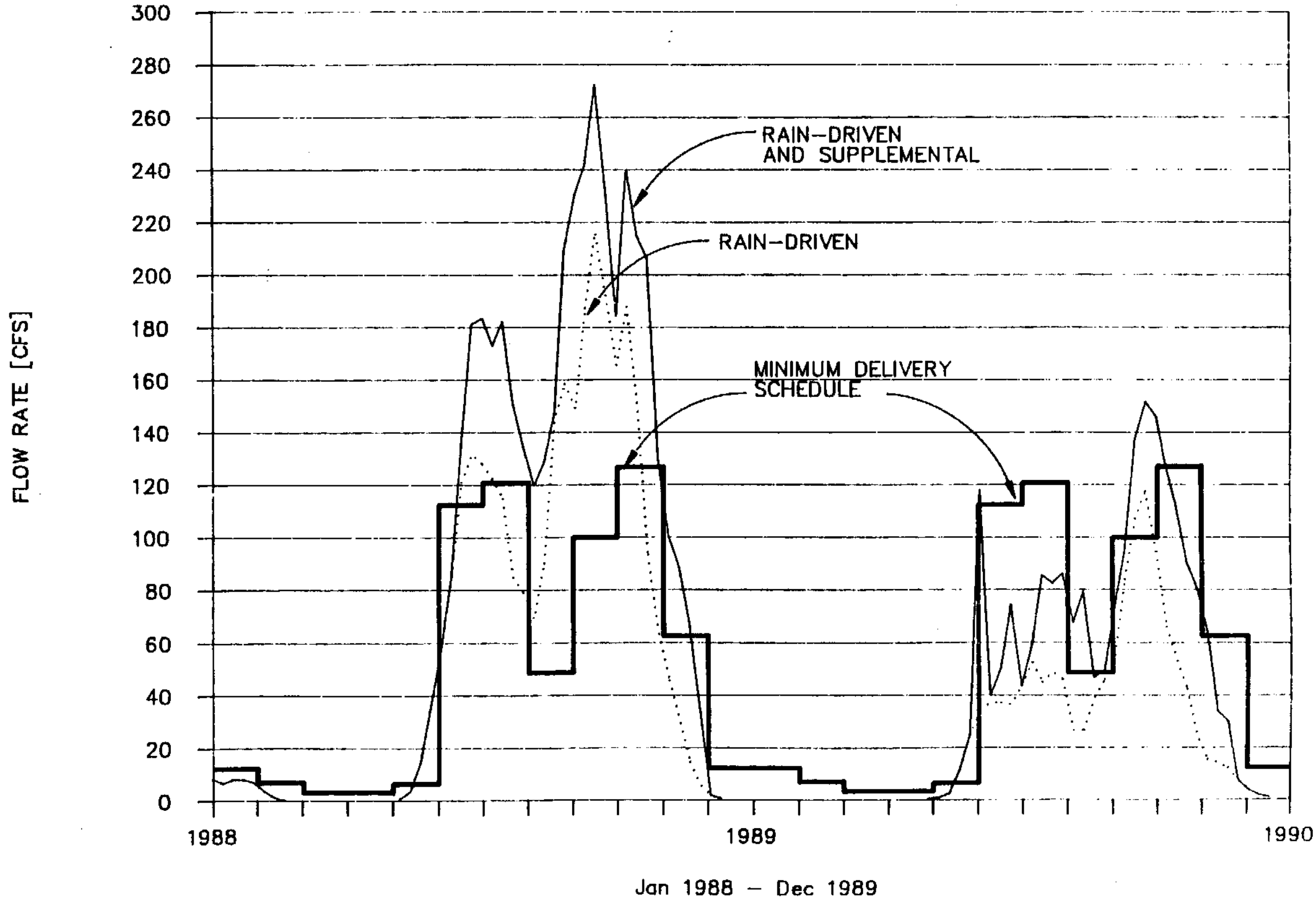



Figure 12. Comparison of Flow Prescribed by the Rainfall Plan with the Minimum Delivery Schedule

B-85

## E. S-332 Capacity

Over the period 1980 to 1989, the maximum S-332 discharge (average weekly rate) as prescribed by the Taylor Slough Rainfall Plan (not including Tropical Storm Dennis in August 1981) was 270 cfs (August 1988 event), 110 cfs higher than the 160 cfs capacity of S-332. To achieve discharges at S-332 that would be required by the proposed plan (under rainfall conditions similar to those experienced during the 1980's), the capacity of S-332 would have to be increased by 110 cfs.

However, other factors should be considered in order to determine the necessary capacity increase. The frequency of prescribed high discharges is one factor. Figure 13 shows the flow at S-332 (as prescribed by the Rainfall Plan during the period 1981-1989) versus the percent of time that this flow was exceeded. If the Rainfall Plan were in effect during the 1980's with the existing S-332 capacity, the pump station would not have been able to deliver the prescribed flow about eight percent of the time. With a 80 cfs increase in S-332 capacity, the prescribed flows would not have been met two percent of the time. Considering this information, the short period of data, and the margin of error associated with using actual data to estimate the supplemental component during the 1980's, an 80 cfs capacity increase is recommended.

The District proposes to achieve the increased capacity of S-332 through the use of a portable pump during the peak wet season months when the existing capacity is not sufficient to deliver the flows prescribed by the Taylor Slough Rainfall Plan.

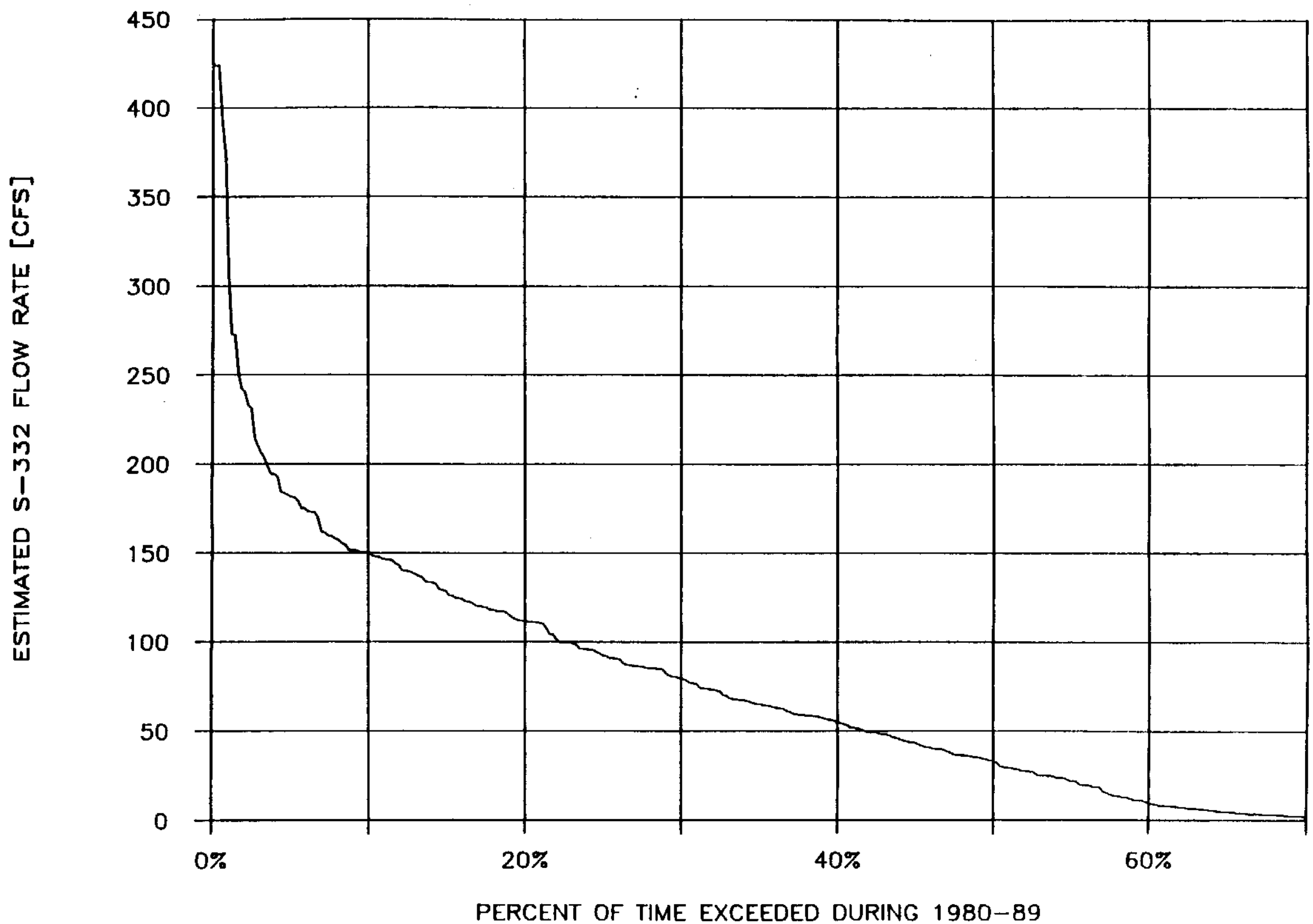



**Figure 13. Estimated S-332 Flow Prescribed by the Rainfall Plan Versus Percent Exceedence**

A-8

A.-8

Appendix 4. C-111 gap profiles.



A.8

A-

# MEMORANDUM

TO: Jorge Marban, Director, Water Resources Division

FROM: Jim Milleson, Environmental Sciences Division

DATE: May 19, 1986

SUBJECT: C-111 Gap Information

Attached is a table depicting the width and ground elevation of each of the 54 gaps in the spoil bank along the south side of C-111. The measurements were taken several years ago by George Still, Homestead Field Station, and I believe the elevations are the average of several spot measurements in each gap, using S-197 HW as the reference. Comparison of the gap elevation with C-111 center line elevations from the design drawings in the DDM show a high degree of consistency.

This information should be useful for your modeling efforts to determine flow through the gaps under various stage and discharge regimes. If you think an on-site inspection would be helpful, we can arrange for a field trip at your convenience.

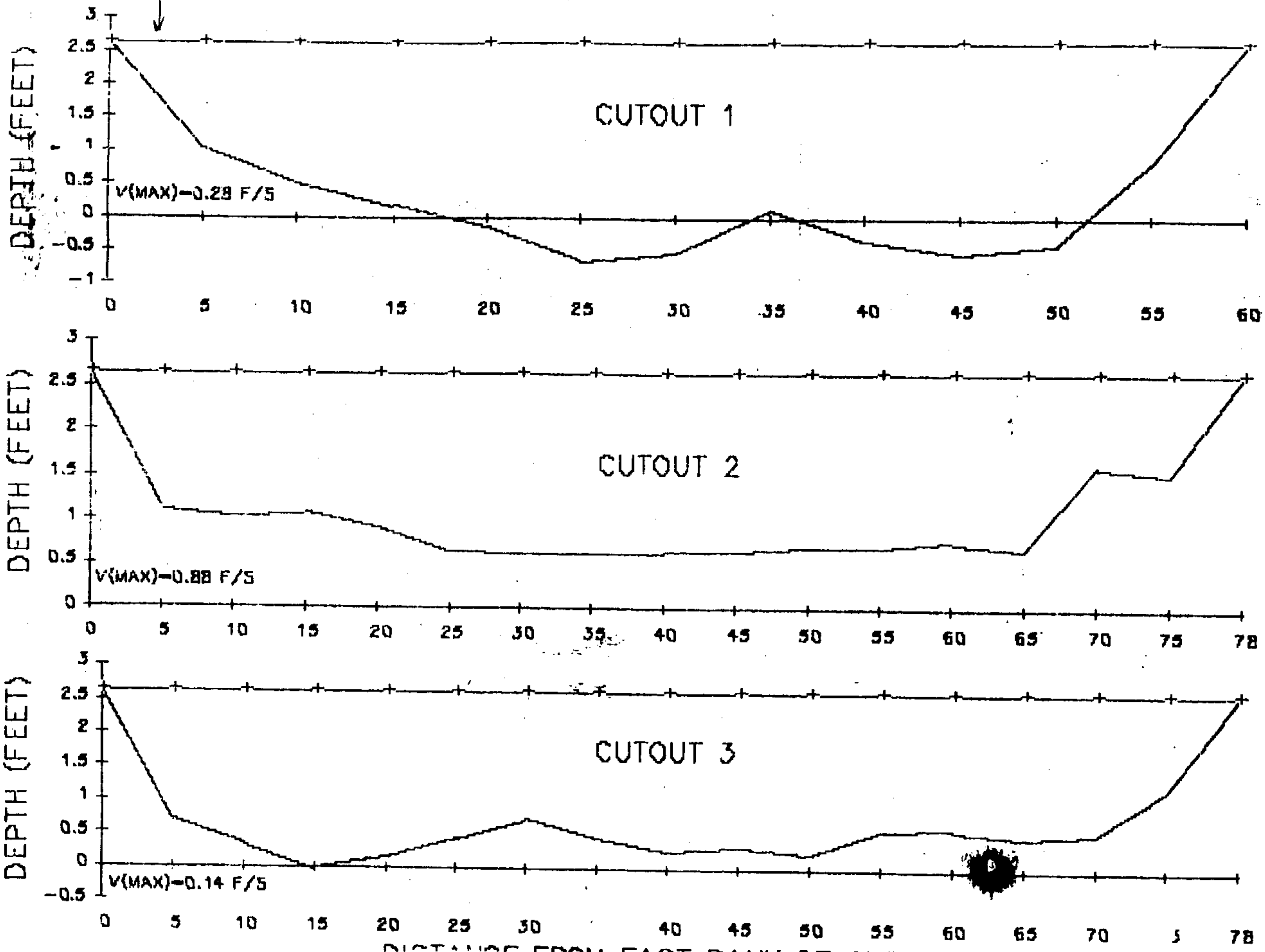
Please let me know if you have any other questions.

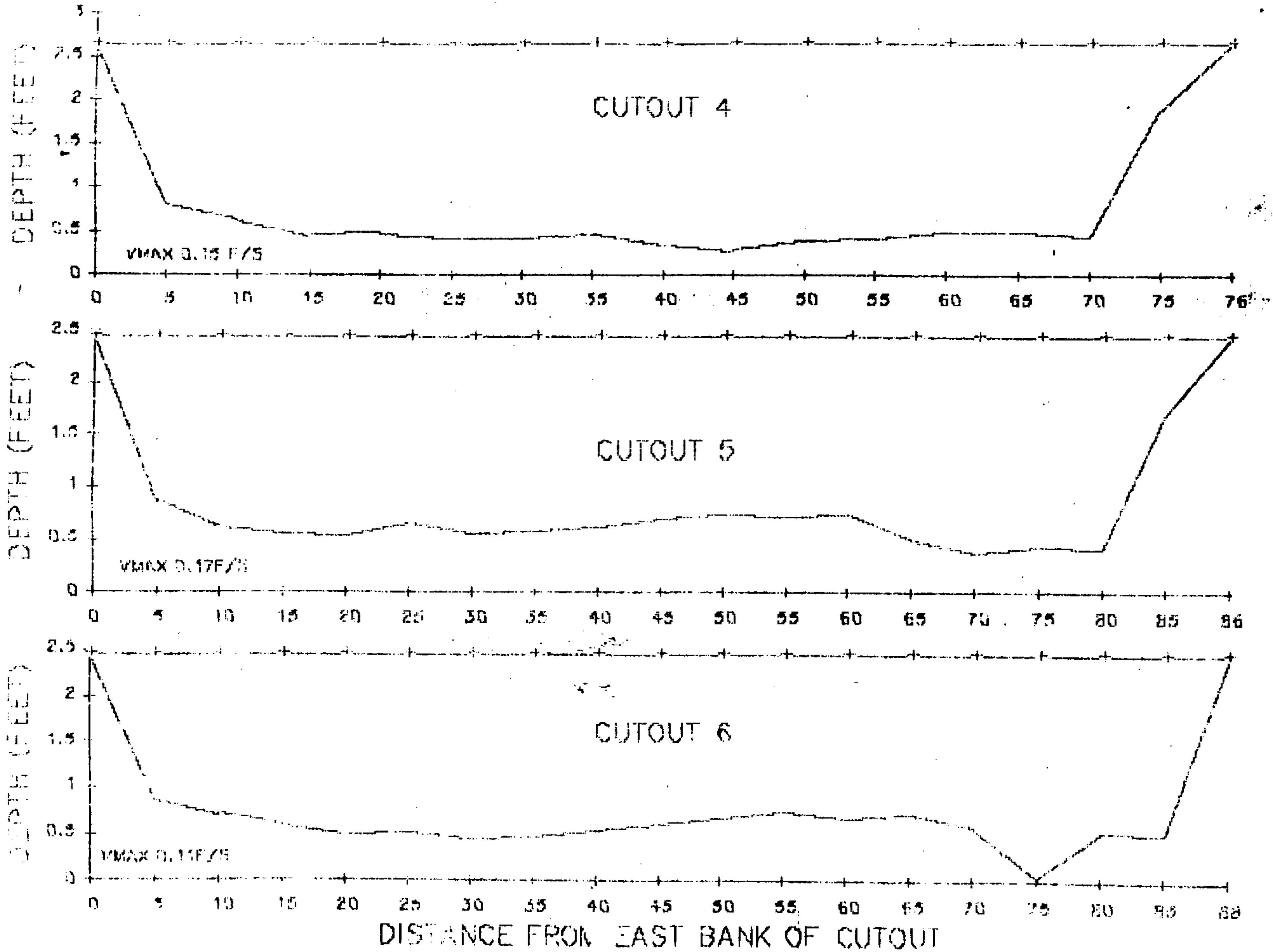
JM:n
Attachment

cc: D. Swift
M. Zaffke
D. Haunert

| GAP # | GAP WIDTH (ft) | GROUND ELEV. (ft.msl) | ELEV.FROM C-111 CENTER LINE (Drawings) | GAP # | GAP WIDTH (ft) | GROUND ELEV. (ft.msl) | ELEV.FROM C-111 CENTER LINE(Drawings) |
|---|---|---|---|---|---|---|---|
| | | | 0.8 | | | | |
| 1 | 75 | .94 | | 28 | 92 | .90 | |
| | | | 0.8 | | | | 0.8 |
| 2 | 77 | .70 | | 29 | 84 | 1.10 | |
| | | | 1.2 | | | | 1.1 |
| 3 | 83 | .94 | | 30 | 77 | .75 | |
| | | | 0.8 | | | | 0.8 |
| 4 | 87 | .99 | | 31 | 107 | .80 | |
| | | | 0.9 | | | | 0.8 |
| 5 | 81 | .94 | | 32 | 95 | .90 | |
| | | | 0.9 | | | | 0.8 |
| 6 | 101 | .94 | | 33 | 72 | .50 | |
| | | | 0.7 | | | | 0.8 |
| 7 | 85 | .94 | | 34 | 98 | 1.30 | |
| | | | 0.9 | | | | 1.0 |
| 8 | 92 | .74 | | 35 | 75 | 1.35 | |
| | | | | | | | 1.2 |
| 9 | 91 | .74 | | 36 | 80 | 1.40 | |
| | | | 0.8 | | | | 0.7 |
| 10 | 91 | .84 | | 37 | 73 | 1.50 | |
| | | | 1.2 | | | | 0.8 |
| 11 | 98 | 1.04 | | 38 | 102 | 1.50 | |
| | | | 0.5 | | | | 1.0 |
| 12 | 99 | 0.50 | | 39 | 97 | 1.45 | |
| | | | | | | | 1.0 |
| 13 | 100 | 0.80 | | 40 | 103 | 1.40 | |
| | | | 0.9 | | | | 1.0 |
| 14 | 79 | 0.90 | | 41 | 90 | 1.55 | |
| | | | 1.0 | | | | 1.3 |
| 15 | 91 | 0.70 | | 42 | 95 | 1.55 | |
| | | | 0.9 | | | | 1.4 |
| 16 | 98 | 0.60 | | 43 | 77 | 1.50 | |
| | | | 0.9 | | | | 1.0 |
| 17 | 99 | 0.90 | | 44 | 92 | 1.40 | |
| | | | 0.9 | | | | 1.1 |
| 18 | 95 | 0.90 | | 45 | 91 | 1.60 | |
| | | | 1.0 | | | | 1.0 |
| 19 | 97 | 1.10 | | 46 | 120 | 1.30 | |
| | | | 0.9 | | | | 1.0 |
| 20 | 113 | .40 | | 47 | 91 | 1.20 | |
| | | | 0.9 | | | | 1.2 |
| 21 | 94 | .20 | | 48 | 112 | 1.20 | |
| | | | 0.9 | | | | 1.4 |
| 22 | 79 | .90 | | 49 | 94 | 1.30 | |
| | | | 0.9 | | | | 1.5 |
| 23 | 94 | .70 | | 50 | 86 | 0.95 | |
| | | | 1.0 | | | | 1.4 |
| 24 | 89 | 1.00 | | 51 | 102 | 1.20 | |
| | | | 1.0 | | | | 1.0 |
| 25 | 84 | .60 | | 52 | 102 | 0.95 | |
| | | | 0.7 | | | | 1.5 |
| 26 | 95 | .35 | | 53 | 107 | 1.25 | |
| | | | 0.8 | | | | 1.5 |
| 27 | 90 | .60 | | 54 | 100 | 1.30 | |
| | | | 0.7 | | | | 1.6 |

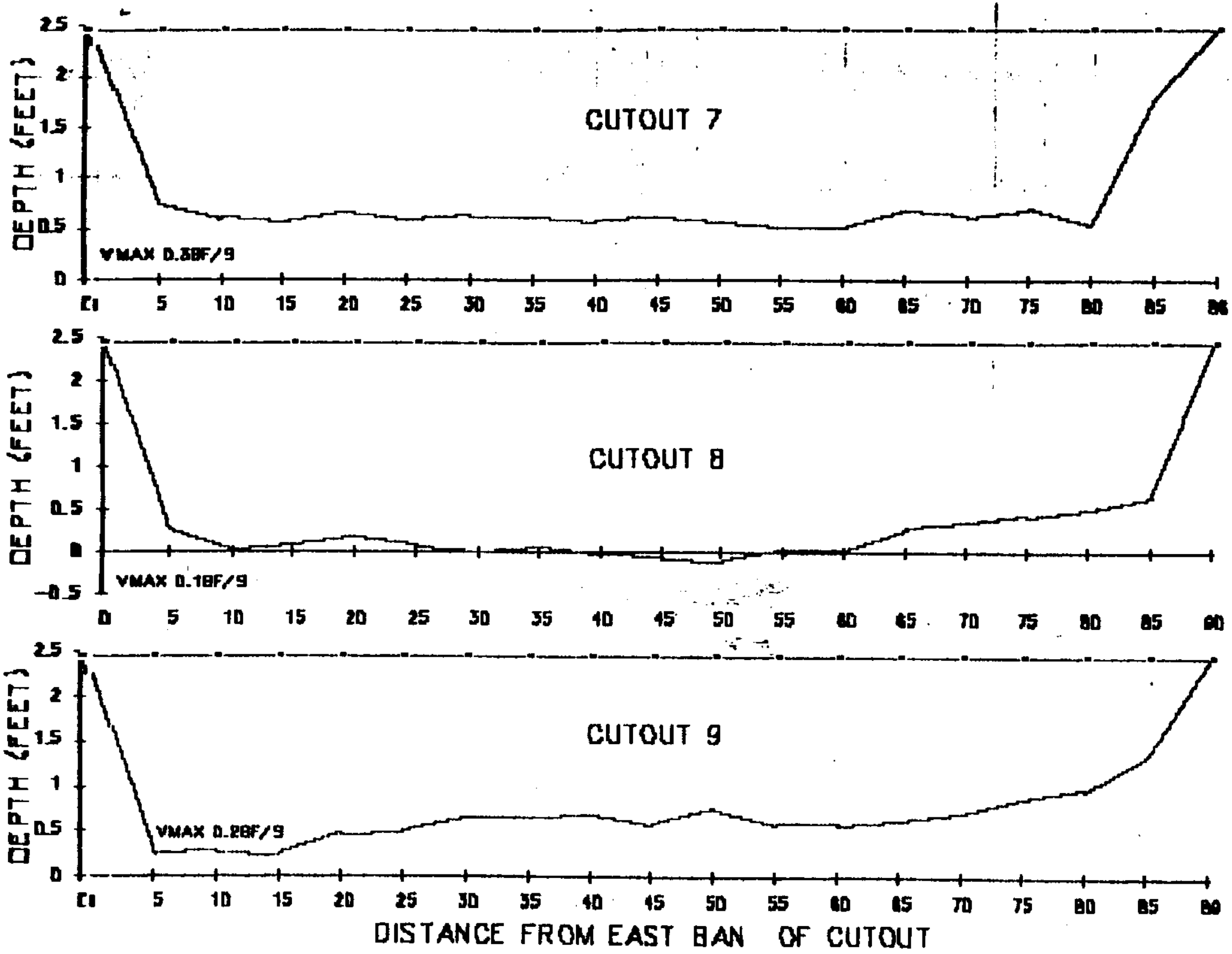
FLOW VELOCITY THROUGH C-111 GAPS

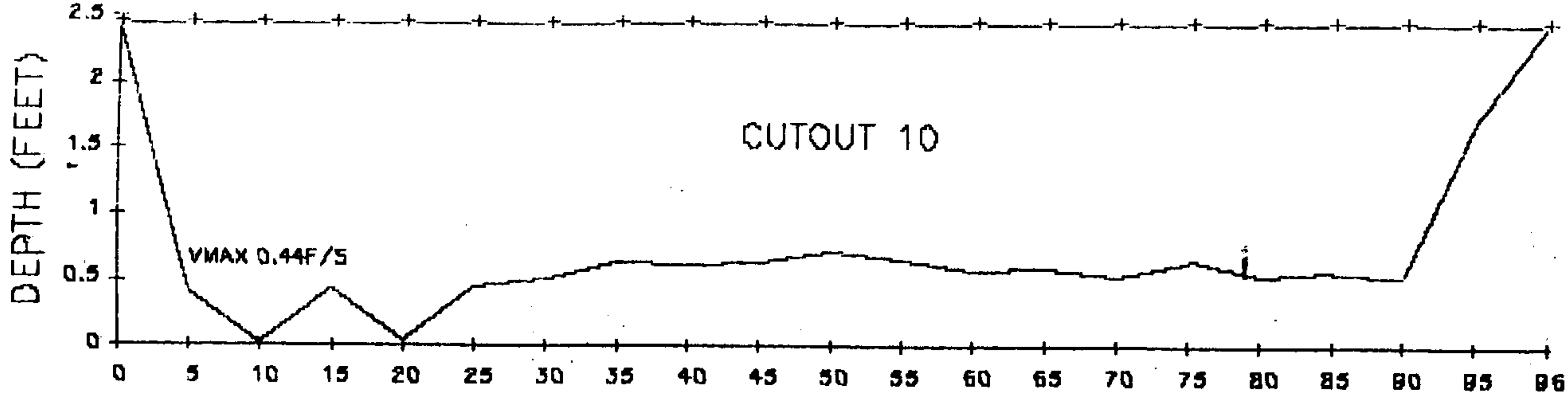


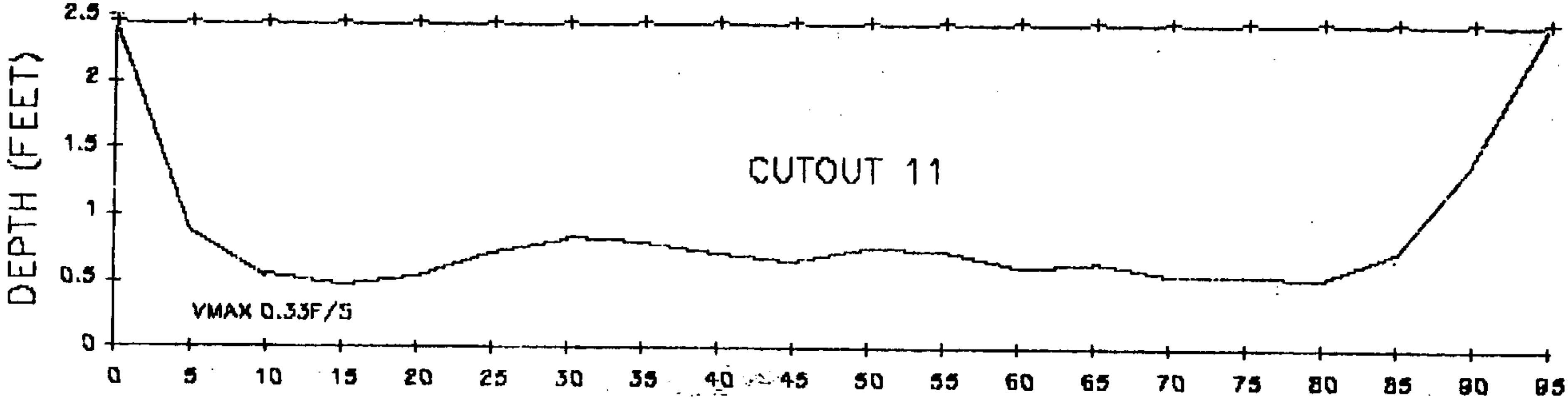


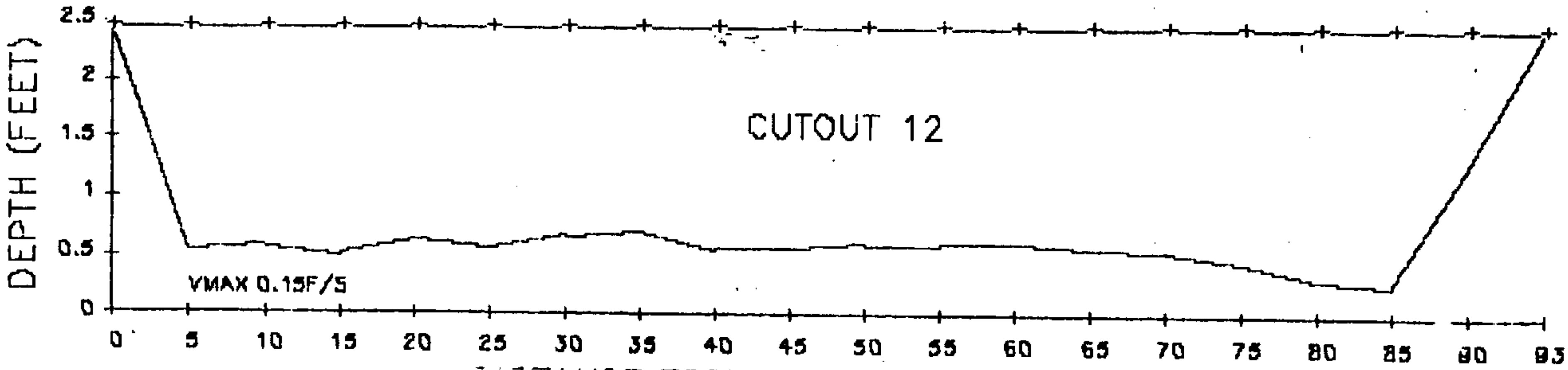
CUTOUT 4
VMAX 0.15 F/S
CUTOUT 5
VMAX 0.17F/S
CUTOUT 6
VMAX 0.11F/S
DEPTH (FEET)
DISTANCE FROM EAST BANK OF CUTOUT

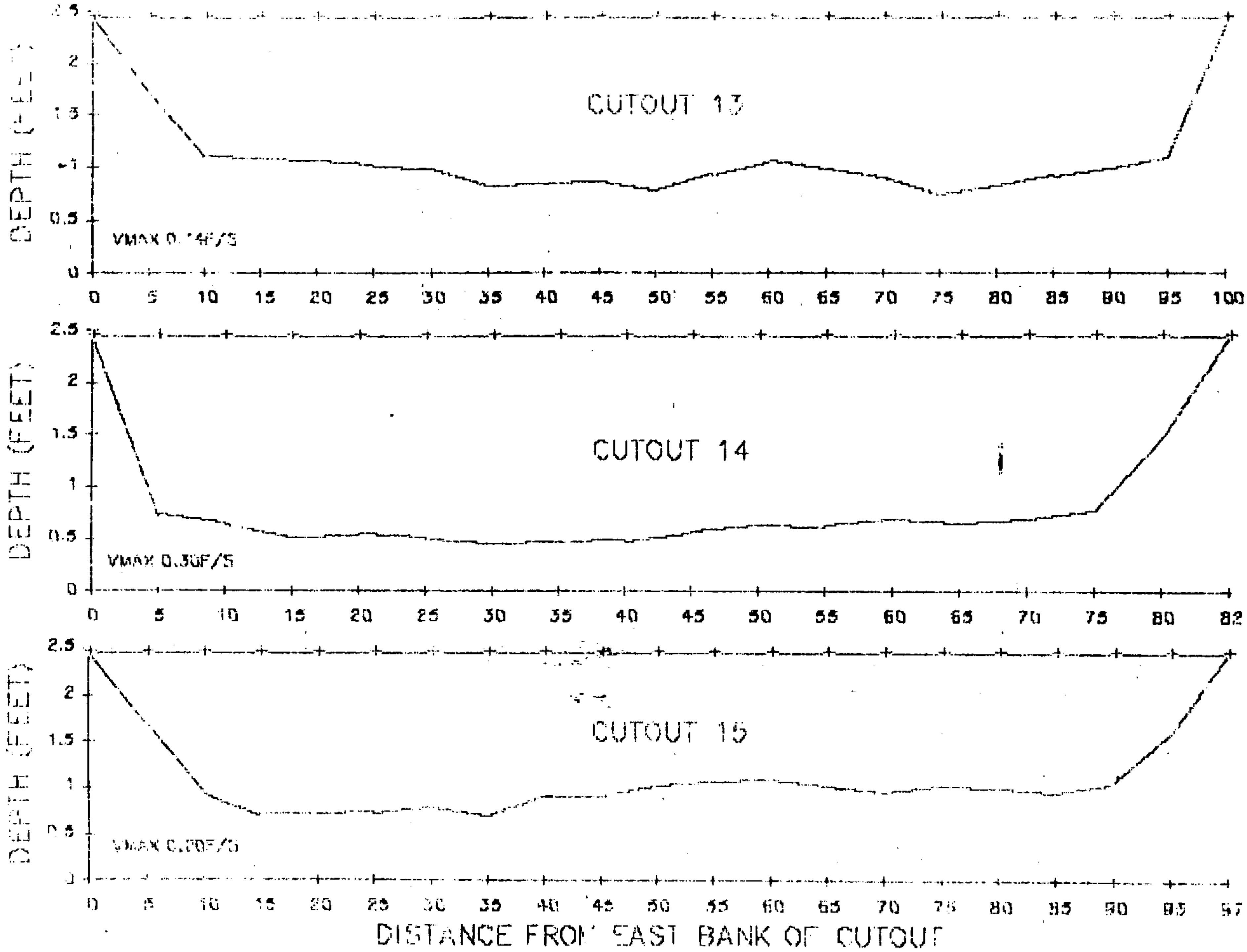

89

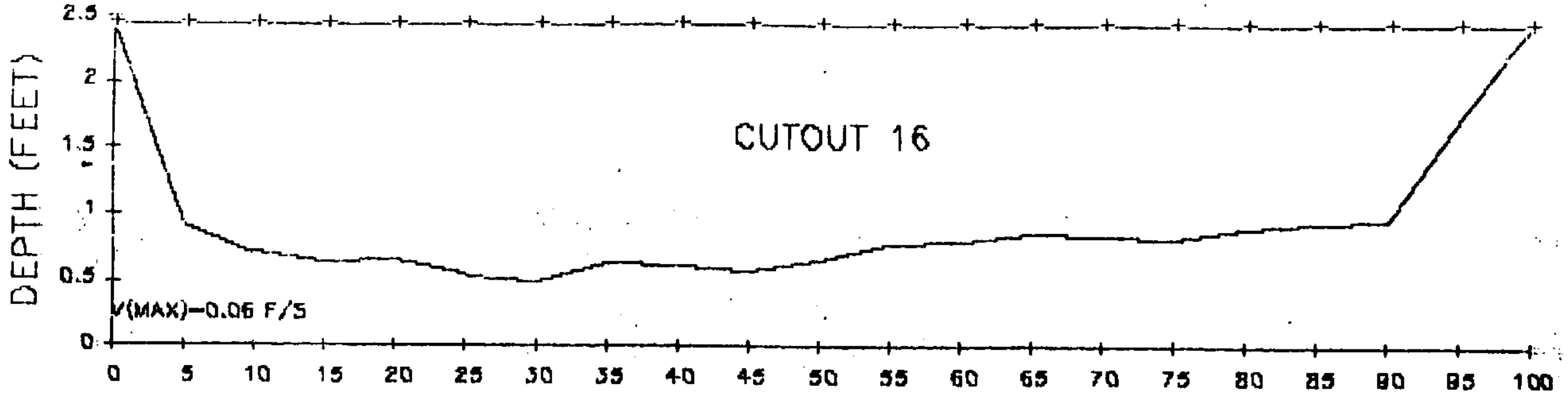

CUTOUT 7
VMAX 0.38F/S
CUTOUT 8
VMAX 0.18F/S
CUTOUT 9
VMAX 0.28F/S
DEPTH (FEET)
DISTANCE FROM EAST BAN OF CUTOUT

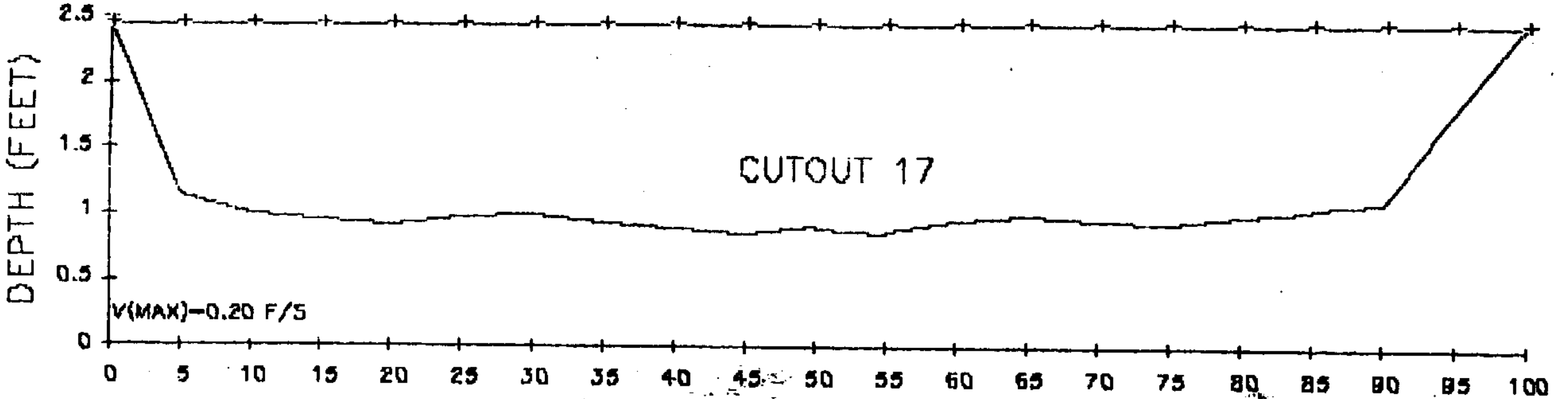

CUTOUT 10
DEPTH (FEET)
VMAX 0.44F/S
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 96

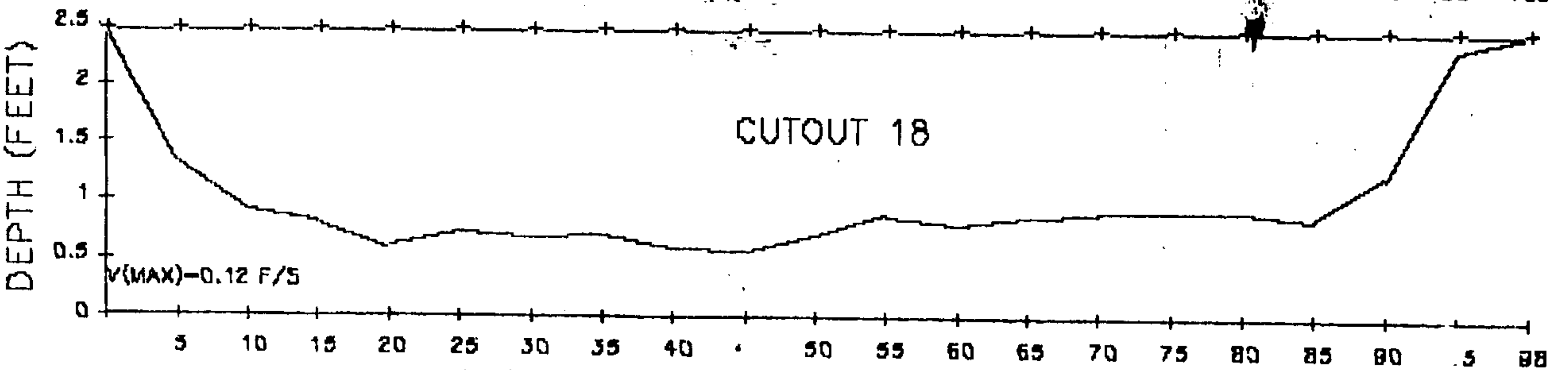

CUTOUT 11
DEPTH (FEET)
VMAX 0.33F/S
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95

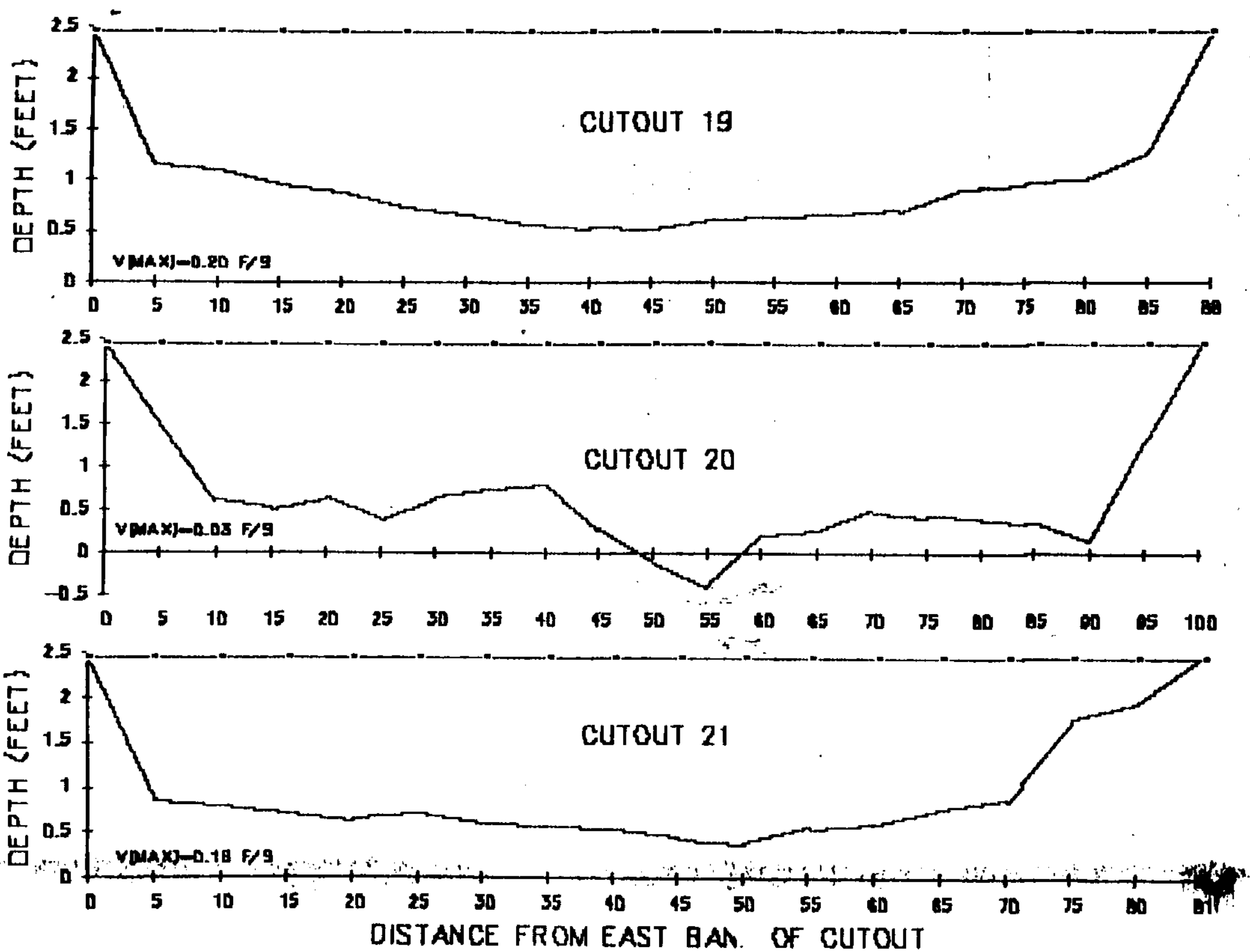

CUTOUT 12
DEPTH (FEET)
VMAX 0.15F/S
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 93


DEPTH (FEET)
CUTOUT 13
VMAX 0.14F/S
DEPTH (FEET)
CUTOUT 14
VMAX 0.30F/S
DEPTH (FEET)
CUTOUT 15
DISTANCE FROM EAST BANK OF CUTOUT

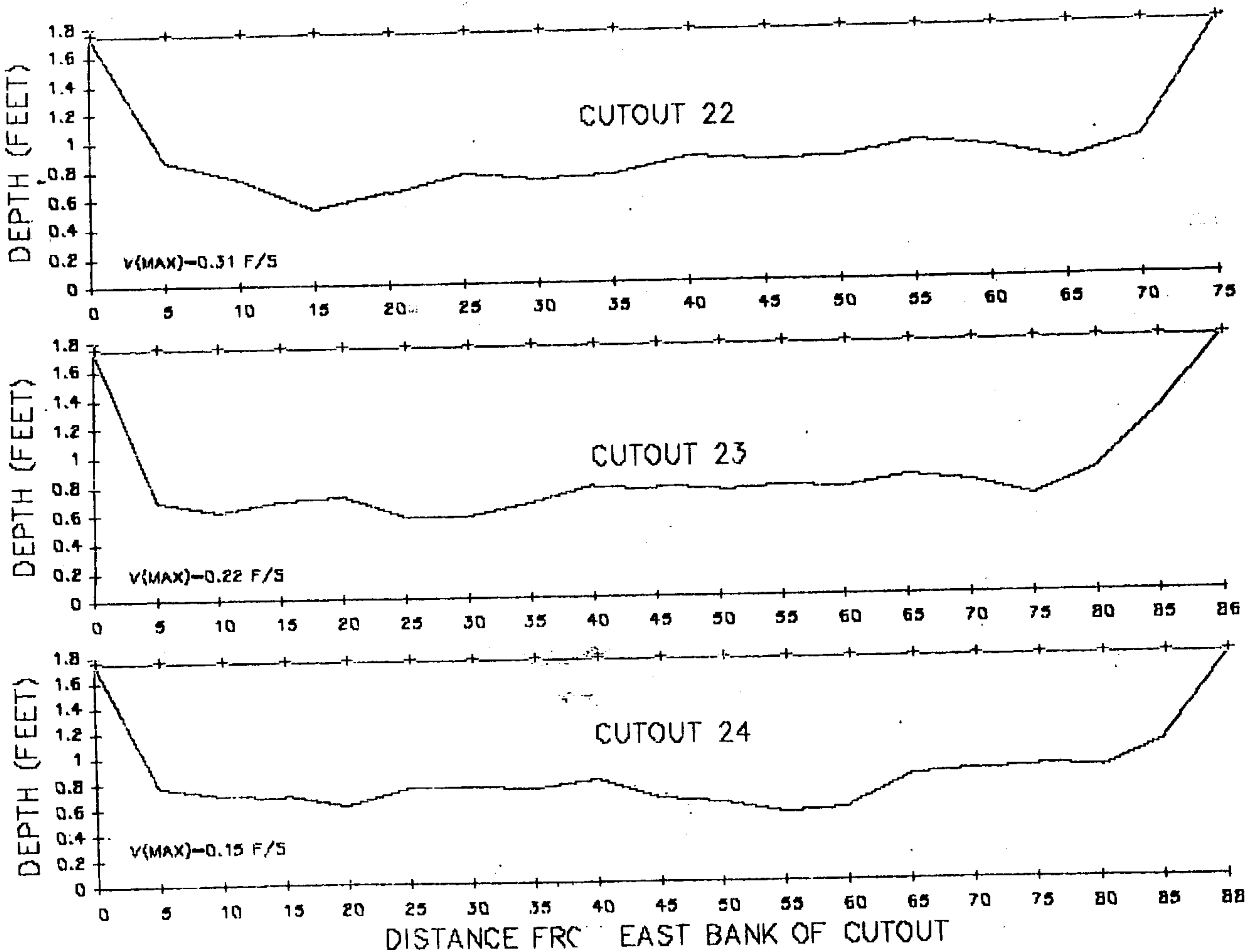

CUTOUT 16
DEPTH (FEET)
V(MAX)—0.06 F/S

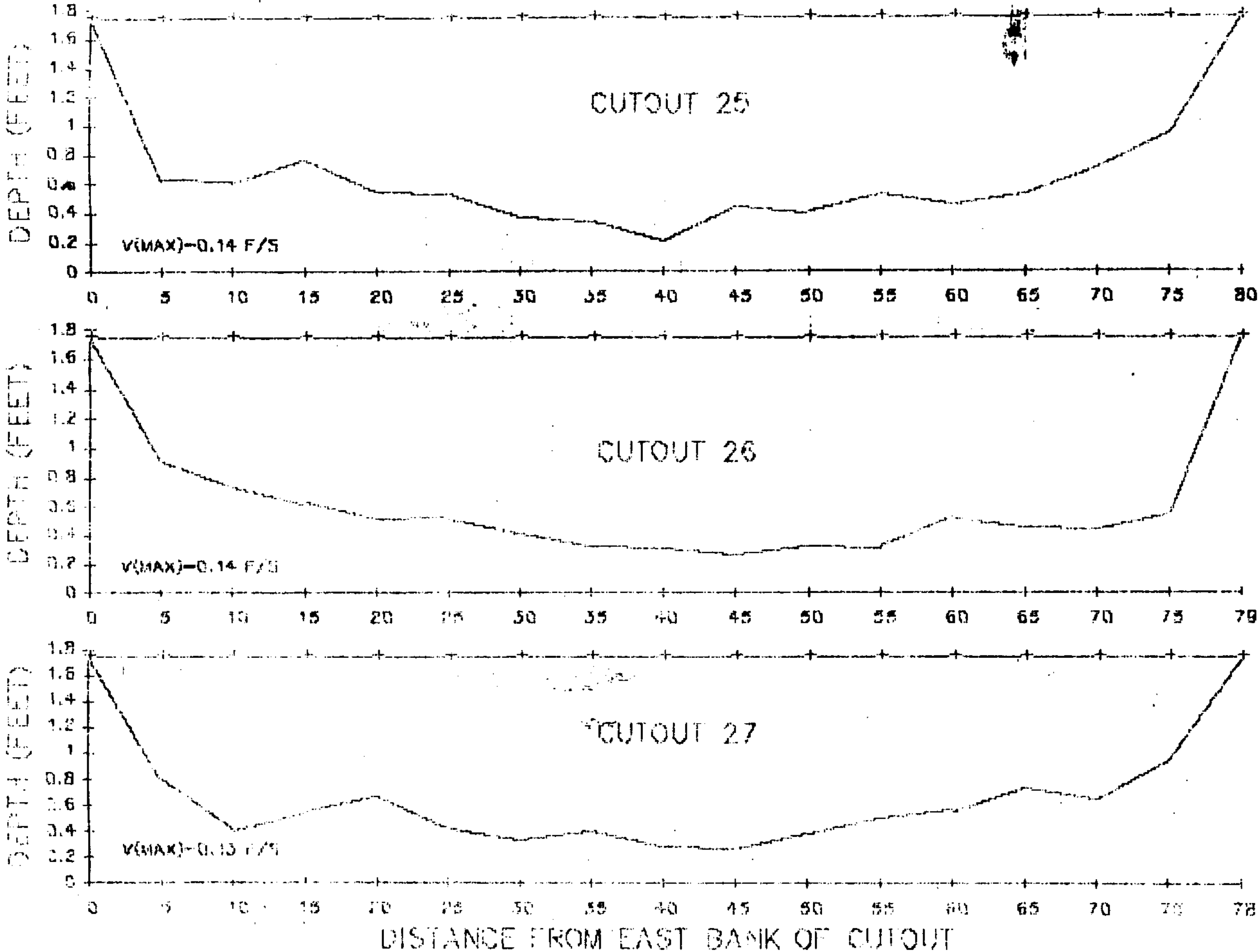

CUTOUT 17
DEPTH (FEET)
V(MAX)—0.20 F/S


CUTOUT 18
DEPTH (FEET)
V(MAX)—0.12 F/S

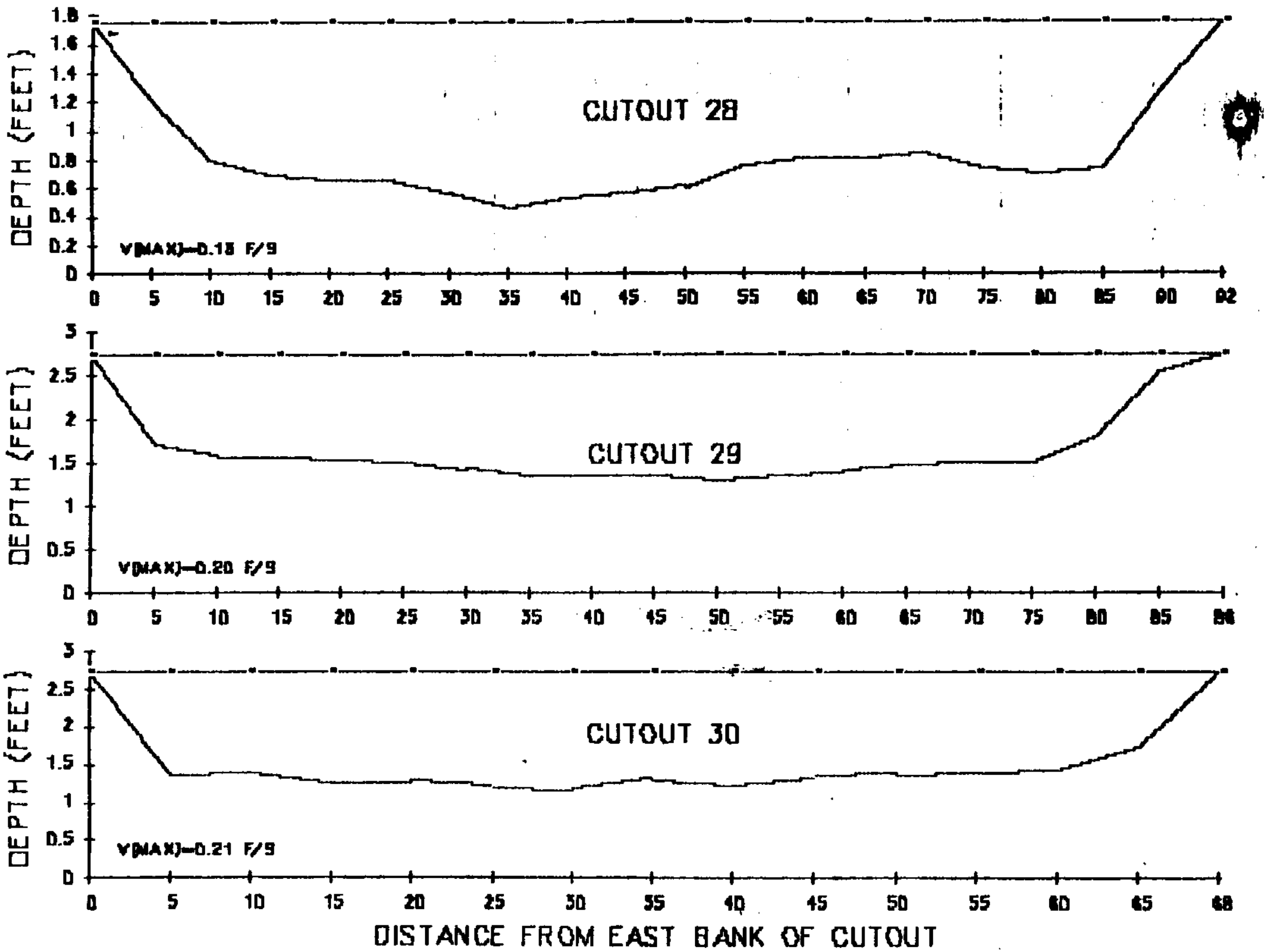


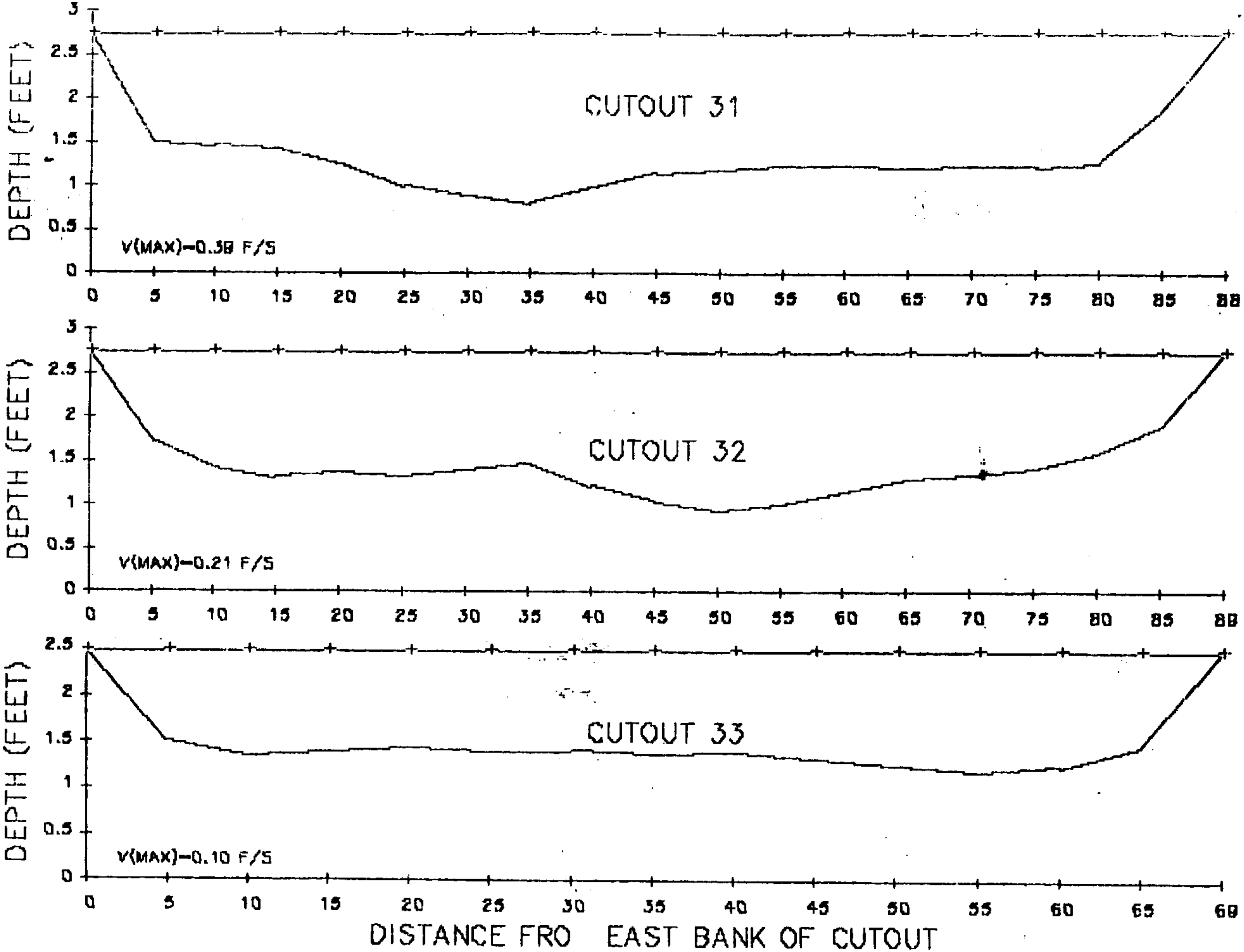
CUTOUT 19
V(MAX)=0.20 F/S
CUTOUT 20
V(MAX)=0.03 F/S
CUTOUT 21
V(MAX)=0.18 F/S
DEPTH (FEET)
DISTANCE FROM EAST BAN. OF CUTOUT


DEPTH (FEET)
CUTOUT 22
V(MAX)=0.31 F/S
DEPTH (FEET)
CUTOUT 23
V(MAX)=0.22 F/S
DEPTH (FEET)
CUTOUT 24
V(MAX)=0.15 F/S
DISTANCE FRC EAST BANK OF CUTOUT



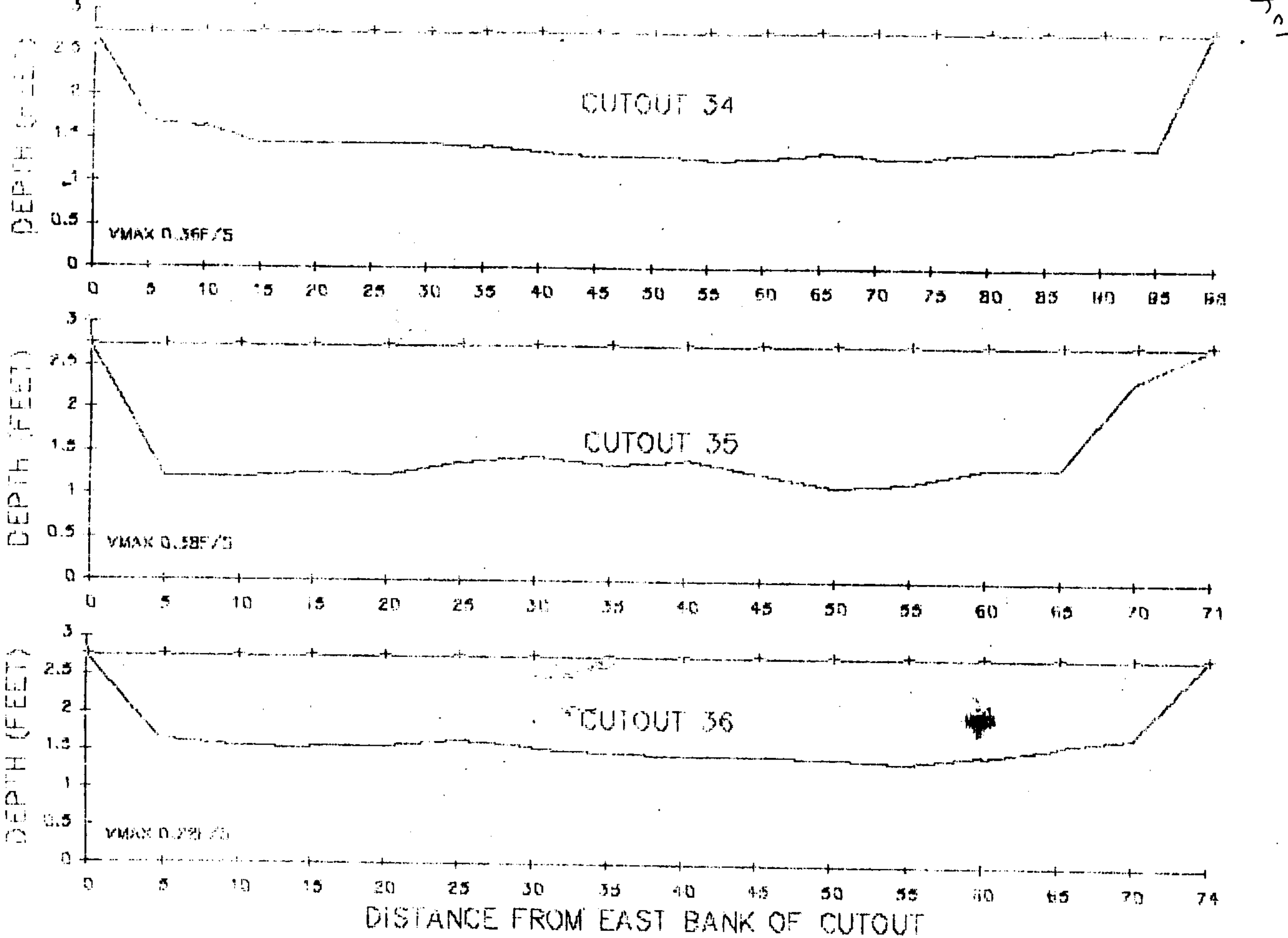
DEPTH (FEET)
CUTOUT 25
V(MAX)=0.14 F/S
CUTOUT 26
V(MAX)=0.14 F/S
CUTOUT 27
DISTANCE FROM EAST BANK OF CUTOUT


CUTOUT 28
V(MAX)=0.18 F/S
CUTOUT 29
V(MAX)=0.20 F/S
CUTOUT 30
V(MAX)=0.21 F/S
DEPTH (FEET)
DISTANCE FROM EAST BANK OF CUTOUT

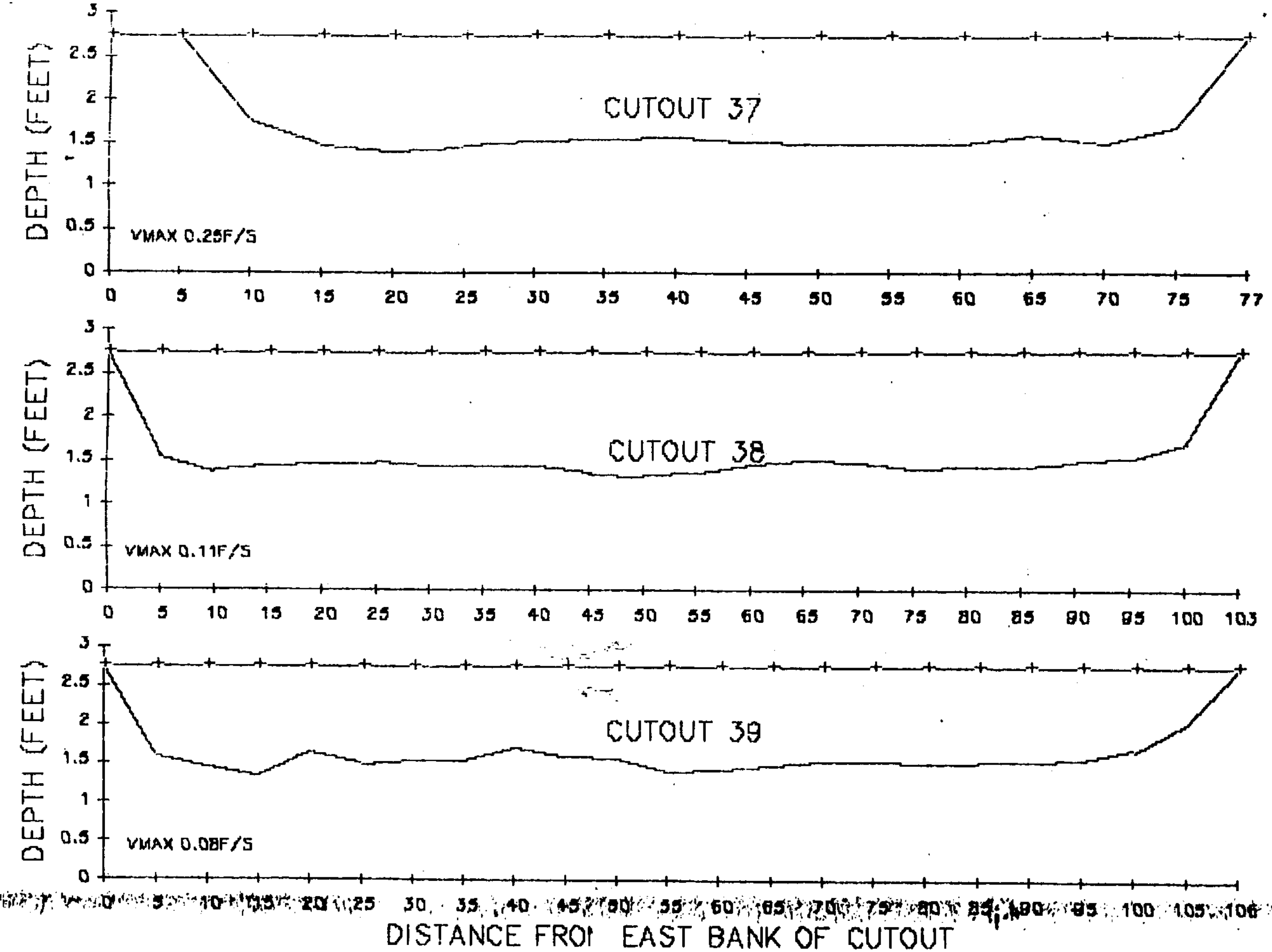


CUTOUT 31
V(MAX)=0.38 F/S
CUTOUT 32
V(MAX)=0.21 F/S
CUTOUT 33
V(MAX)=0.10 F/S
DEPTH (FEET)
DISTANCE FRO EAST BANK OF CUTOUT

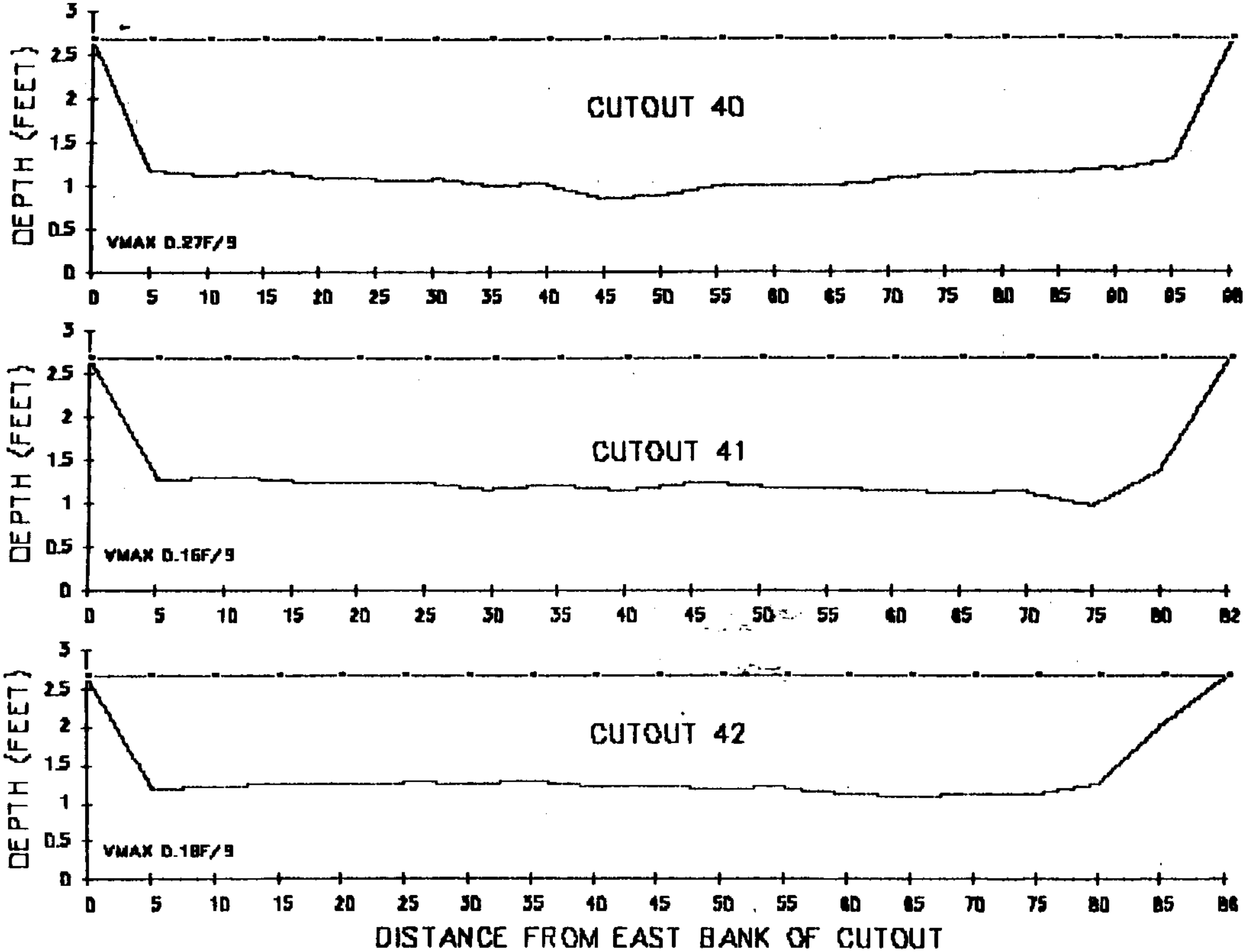

103



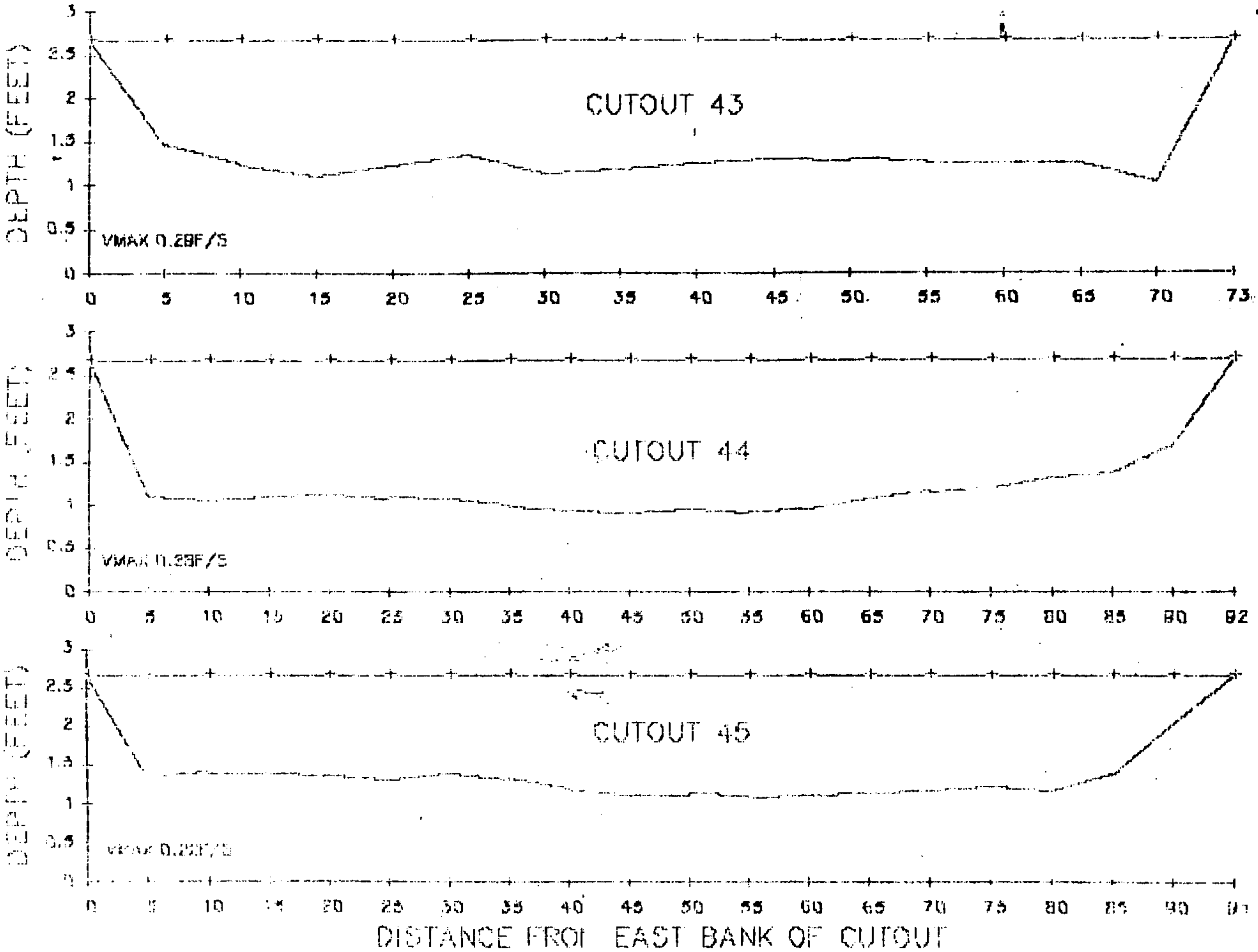
CUTOUT 34
VMAX 0.36F/S
CUTOUT 35
VMAX 0.38F/S
CUTOUT 36
DEPTH (FEET)
DISTANCE FROM EAST BANK OF CUTOUT



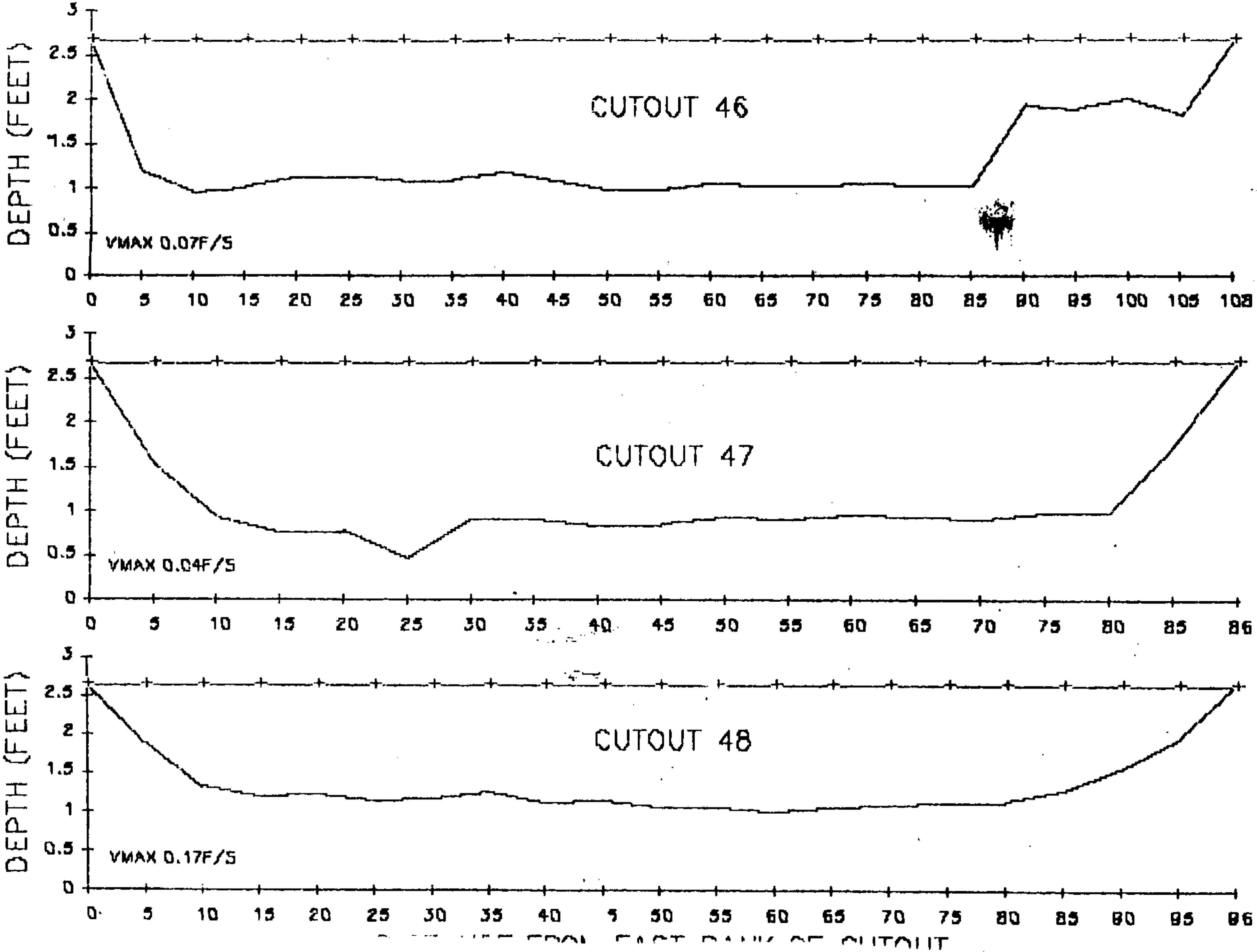
DEPTH (FEET)
CUTOUT 37
VMAX 0.25F/S
DEPTH (FEET)
CUTOUT 38
VMAX 0.11F/S
DEPTH (FEET)
CUTOUT 39
VMAX 0.08F/S
DISTANCE FROM EAST BANK OF CUTOUT



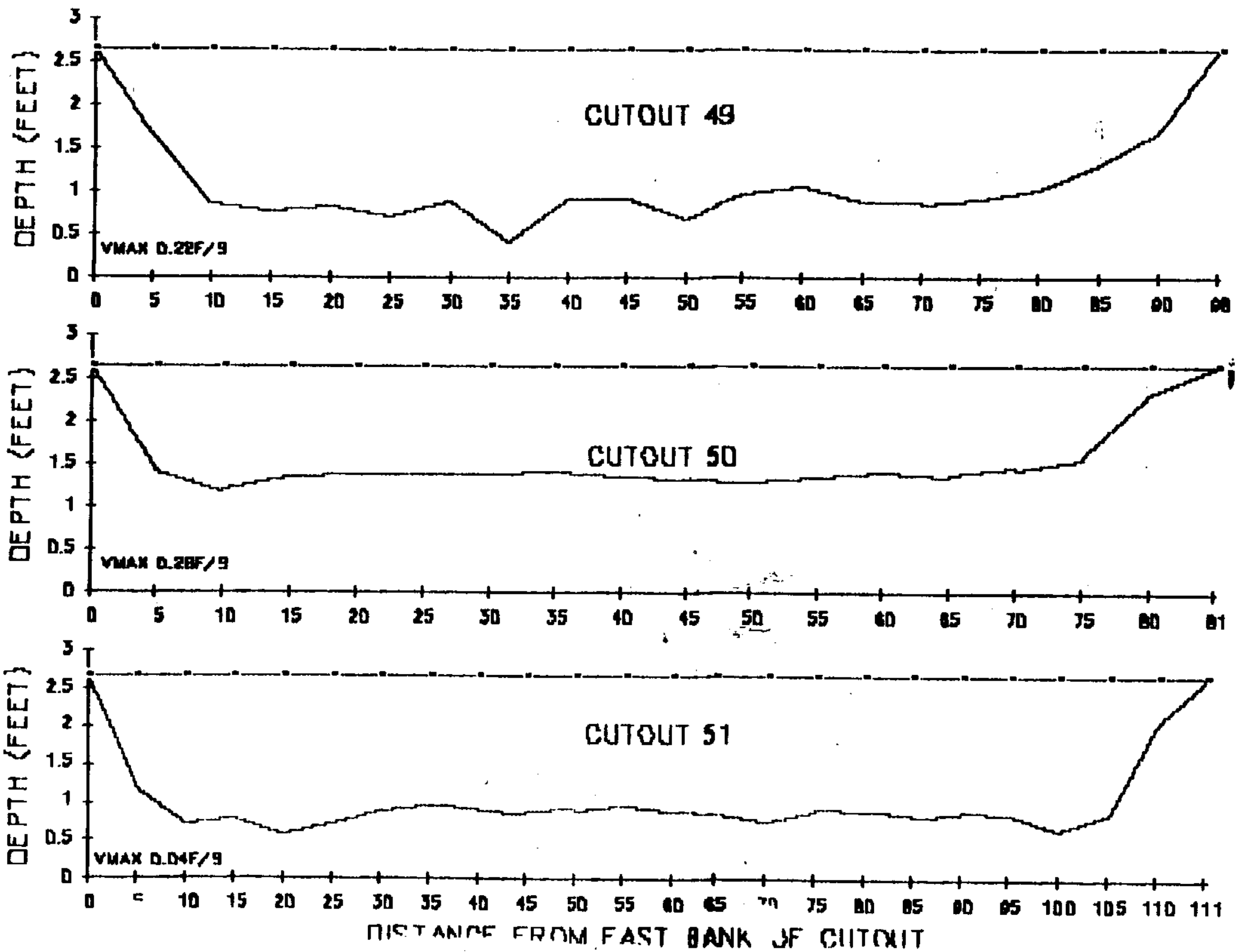
CUTOUT 40
VMAX 0.27F/S
CUTOUT 41
VMAX 0.16F/S
CUTOUT 42
VMAX 0.18F/S
DEPTH (FEET)
DISTANCE FROM EAST BANK OF CUTOUT

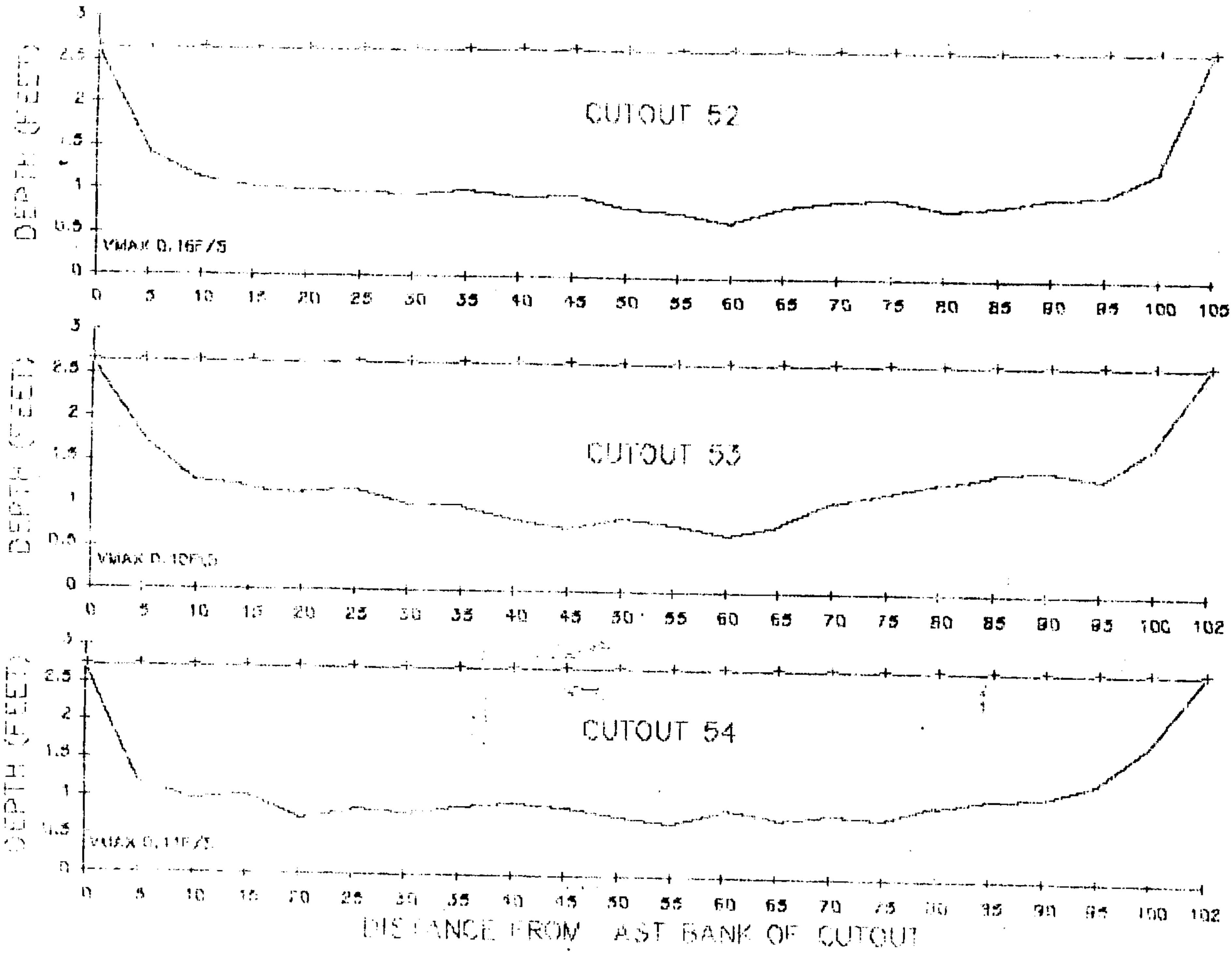


DEPTH (FEET)
CUTOUT 43
VMAX 0.28F/S
CUTOUT 44
VMAX 0.28F/S
CUTOUT 45
DISTANCE FROM EAST BANK OF CUTOUT



CUTOUT 46
DEPTH (FEET)
VMAX 0.07F/S
CUTOUT 47
DEPTH (FEET)
VMAX 0.04F/S
CUTOUT 48
DEPTH (FEET)
VMAX 0.17F/S


CUTOUT 49
VMAX 0.22F/S
CUTOUT 50
VMAX 0.28F/S
CUTOUT 51
VMAX 0.04F/S
DEPTH (FEET)
DISTANCE FROM EAST BANK OF CUTOUT


CUTOUT 52
VMAX 0.16F/S
CUTOUT 53
CUTOUT 54
DEPTH (FEET)
DISTANCE FROM EAST BANK OF CUTOUT

Appendix 5. Water budget contract for C-111 and ENP Eastern Panhandle.

ATTACHMENT A

# Surface Water and Groundwater Responses to C-111 Canal Operations in the Eastern Panhandle Basin of Everglades National Park

Submitted by

Robert Johnson (South Florida Research Center, Everglades National Park)

Robert Fennema (Dept. of Civil and Environmental Engineering, Florida International University)

## Introduction

The C-111 canal and its associated control structures S-176, S-177, and S-18C were completed in 1967 and formed the southernmost portion of an extensive canal system in Dade County designed for flood control and water supply for the lower east coast. The lower reach of the C-111 canal traverses a large freshwater wetland area just north of the Eastern Panhandle basin in Everglades National Park prior to discharging into Manatee and Barnes Sound. A number of factors including restoration of wetland hydroperiods, restoration of estuarine salinity and productivity, and a need to provide increased flood protection for south Dade agricultural areas in the basin lead the South Florida Water Management District to request the Army Corps of Engineers to prepare a general design memorandum to explore structural modifications in the C-111 canal system.

Several local government agencies are currently conducting research or monitoring activities in the lower C-111 basin related to the Corps of Engineers design study. The U. S. Geological Survey was contracted by the Water Management District in 1985 to install a network of hydrologic stations in the area including 7 water level recording stations, a salinity monitoring station in Manatee Bay, and observation wells to monitor the salt front in the underlying aquifer.

In the early 1980's Everglades National Park established a network of stations in the nearshore area of Northeast Florida Bay to monitor salinity, tides, and rainfall to examine the potential impacts of water management operations in the C-111 canal system on the downstream estuaries. In 1985, the Park established a line of discontinuous staff gages along the Park boundary south of the C-111 canal to monitor surface water conditions in the basin. Later in 1986, the Park added a station in the central portion of the Eastern Panhandle basin to continuously record surface water and groundwater levels in the area.

In 1986, the Water Management District began a series of environmental studies in the lower C-111 basin to develop an understanding of environmental/hydrologic relationships in the area as a preliminary step to evaluating C-111 restoration and water management alternatives. Later in 1987, the district established a memorandum of agreement with the Park which included establishing additional estuarine montoring stations in Florida Bay and ecological studies along several tidal creeks draining into the nearshore areas of Northeast Florida Bay.

With all of the above monitoring and research projects, little is known about the wetlands south of the C-111 canal and the effects of the canal system on the hydrology of the Eastern Panhandle basin. This area is most important since it represents the area most affected by current canal management operations and proposed structural modifications.

Research Objectives

The purpose of the proposed research is to study the hydrologic system of the lower C-111 canal and the Eastern Panhandle basin between the canal and Northeast Florida Bay. The study will contribute to our understanding of the lower C-111 canal system and aid in evaluating the effects of proposed restoration and water management alternatives. The proposed research investigations will include:

1. Development of a water budget for the lower C-111 canal system between structures S-18C and S-197;

2. Evaluation of surface water responses in the Eastern Panhandle basin to structure discharges and stages in the C-111 canal;

3. Evaluation of groundwater responses in the Eastern Panhandle basin to structure discharges and stages in the C-111 canal;

4. Examination of the responses of the saltwater/ freshwater interface to C-111 canal discharges and stages.

The first objective will provide quantitative information on the flow of surface water and groundwater between the underlying aquifer, the C-111 canal, and the adjacent wetlands. The evaluation of downstream responses (objectives 2 and 3) will be accomplished using numerical hydrologic models and appropriate functional relationships developed through statistical approaches if sufficient data are available. The final objective will be examined only at a preliminary level through statistical approaches where appropriate.

Research Schedule

The first phase of the study (approximately 2 months) will be primarily field work establishing and surveying a network of hydrologic monitoring stations. This network will include continuous water level recorders and staff gages in and adjacent to the C-111 canal as well as recorders, staff gages, and groundwater observation wells in the wetlands south of the canal (Fig. 1).

The second phase of the study (12 months) will be devoted to monitoring the hydrology network collecting the continuous and discontinuous water level data, rainfall and evaporation data, and performing conductivity profiles in the deep groundwater observation wells. This phase will also examine methods of quantifying surface water inflows into the C-111 canal through the culverts on the north side of the canal, surface water outflows through the cutouts on the south side of the canal, and seepage estimates between the canal and the underlying aquifer. If the above surface water examinations appear to be sufficiently accurate they will be used to develop rating curves for the culverts and cutouts along the C-111 canal that will be appied throughout the study period.

The final phase of the study (approximately 6 months) will involve data analysis and evaluation studies producing the water budget for the lower C-111 canal and determining the surface water and groundwater responses in the Eastern Panhandle basin to canal operations. During this phase the District's South Florida Water Management Model and a numerical model developed by Robert Fennema will be used to explore the effects of various restoration and water management options proposed for the C-111 canal system.

Methodology

Surface water inflows into the C-111 canal from the 9 culverts on the north side of the canal will be evaluated by developing culvert rating curves for selected culverts based on field velocity measurements and stages on the upstream sides of the culverts. If a good rating curve can be developed for individual culverts then a stage/discharge relationship for all of the culverts will be attempted using field velocity measurements at selected culverts and stages a three recorders spaced along the north side of the canal.

Surface water outflows through the cutouts on the south side of the C-111 canal will be evaluated by attempting to develop rating curves for selected cutouts. This again will be based on field measured velocities using either flow meters or tracer techniques depending on which is the most appropriate. If good rating curves can be developed for selected cutouts then a stage/discharge for all of the cutouts will be attempted using a set of 3 to 4 stage recorders spaced along the south side of the canal.

Rainfall and evaporation effects will be incorporated using the existing network of 5 raingages and 2 evaporation sites in the general study area. Initial estimates for evaporation will be based on evaporation pan estimates with pan coefficients developed by researchers in the Park.

Seepage estimates between the C-111 canal and the underlying aquifer will be made using field mesurements of groundwater flow rates from shallow observation wells installed along the northern and southern sides of the canal near the locations of the proposed water level recorders. Field mesurements of groundwater flow rates and directions will be determined using the Park's groundwater flow meter based on calibration methods developed for the Taylor Slough area.

The combination of the above surface water and groundwater field measurements, rainfall inputs, evaporation losses, and published discharge data for the S-18C and S-197 control structures should provide the best estimated water budget for the lower C-111 canal. The results of this water budget will be used as input to the numerical hydrologic models described above and in the development of functional relationships between the C-111 canal, the downstream wetlands and underlying aquifer.

Overall Relevancy

The proposed research project will contribute significantly to our understanding of the lower C-111 canal system and its effects on the surface water and groundwater resources of the Eastern Panhandle basin. The large amount of hydrologic data that will be collected during this study will provide the information needed to begin the numerical modeling process which can be used to explore the effects of various restoration and water mangement options proposed for the C-111 canal.

It is hoped that the hydrologic network established during this project would be maintained beyond this initial study to provide the basis of evaluations for proposed C-111 demostration projects or major structural modifications in the canal system. Additional research and development of a well calibrated and verified numerical model would also increase our understanding of the hydrologic processes occurring in the Eastern Panhandle wetlands and the underlying aquifer, and the hydrologic link between these two systems.

## ATTACHMENT B

## BUDGET BREAKDOWN (C111 Cooperative Study)

| CATEGORY | ENP COSTS | SFWMD COSTS | TOTAL | COMMENTS |
|---|---|---|---|---|
| <u>Salary</u> | | | | |
| Robert Fennema | ----- | $6,250. | $6,250. | (half time, 3 mo.) |
| Student | ----- | $7,000. | $7,000. | (part time, 12 mo.) |
| Student | ----- | $2,100. | $2,100. | (part time, 3 mo.) |
| <u>Fringe Benefits</u> | | | | |
| Robert Fennema | ----- | $1,813. | $1,813. | (29% for 3 months) |
| <u>Travel Expenses</u> | | | | |
| Automobile | ----- | $1,000. | $1,000. | (travel to the field) |
| Helicopter | $7,000. | $3,000. | $10,000. | (travel in the field) |
| <u>Supplies</u> | | | | |
| Field supplies | ----- | $5,000. | $5,000. | (data loggers, etc.) |
| Lab supplies | ----- | $500. | $500. | (lab chemicals, etc.) |
| <u>Indirect Costs</u> | ----- | $3,933. | $3,933. | (20% of FIU costs) |
| TOTAL | $7,000. | $30,596. | $37,596. | |

CP-S

# MEMORANDUM

TO: P. B. Rhoads, Director, Dept of Research & Evaluation

THROUGH: Jorge Marban, Director, Water Resources Div., DRE Jan

FROM: Ray Santee, Staff Engineer, WRD, DRE

DATE: November 8, 1989

SUBJECT: Hydrologic Studies - C-111
Contract No. 399-M86-0344

This memorandum is in reference to contract No. 399-M86-0344A2 the District has with the National Park Service, Everglades National Park (ENP) for the hydrologic study of the lower C-111 basin. The purpose of the memorandum is to request that the Operations Support Division (Operation and Maintenance Department) to advise ENP ahead of time of the manual operation of S-18C and/or the operation of S-331 pump station, and document the need for a no cost contract extension to continue the field monitoring through at least half (through August 1990) of the wet season of year 1990.

A brief summary of background information as well as the status of the contract and any problems encountered is attached.

RS/nw
Attachments

c: S. Sculley
L. Wedderburn
D. Slyfield
C. Neidrauer

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## I. Background

The C-111 drainage basin covers an area of approximately 109 square miles in central Dade County and provides surface water deliveries to the Taylor Slough and the eastern panhandle of Everglades National Park. Large changes in water levels have occurred throughout the basin in response to additional demands placed on the system by urban, agricultural, and environmental interests. The changes in water management have altered the hydrology of the wetlands, particularly in the headwaters of Taylor Slough and the lower C-111 canal system downstream of S-18C. Reductions in the canal optimum water levels and wet season pumping at S-331 to provide additional flood protection have lowered groundwater levels in the upstream basin and transferred large volumes of water into the downstream wetlands and estuaries. The alteration of stages has led to conflicts between the National Park Service (ENP), the South Florida Water Management District (SFWMD), and the U. S. Army Corps of Engineers (COE).

The above agencies undertook monitoring and research projects to explore structural modifications in the C-111 canal system. Bob Johnson, ENP, and Robert Fennema, Florida International University (FIU), point out that little is known about the wetlands south of C-111 canal and the effects of the canal system on the hydrology of the eastern panhandle basin. They proposed a project entitled <u>Surface Water and Groundwater Responses to C-111 Canal Operations in the Eastern Panhandle Basin of Everglades National Park</u> (Attachment A) to study the hydrologic system of the lower C-111 canal and the eastern panhandle basin between the canal and the northeast Florida Bay. The proposed research investigations have included:

1. Development of a water budget for the lower canal system between S-18C and S-197.

2. Evaluation of surface water and groundwater responses in the eastern panhandle basin to structure discharges and stages in the C-111 canal.

3 Evaluation of the responses of the saltwater/freshwater interface to C-111 canal discharges and stages.

An agreement for contractual services between SFWMD and NPS/ENP for the study was developed. An amendment to the agreement was prepared for a hydrologic study to be undertaken cooperatively between ENP (Bob Johnson) and FIU (Dr. Fennema) with approximately $30,000 funded by the District. The amendment was approved in November-December 1987. Procedural delays in contractual agreements between ENP and FIU have caused the project to slip one year, consequently, the project began in December 1988. The final progress report, briefly describing success in meeting all tasks outlined in Attachment A, is now due March 1, 1990. A meeting was held October 11, 1989, at the District with Bob Johnson and Dr. Fennema to discuss the status of the project and any problems encountered.

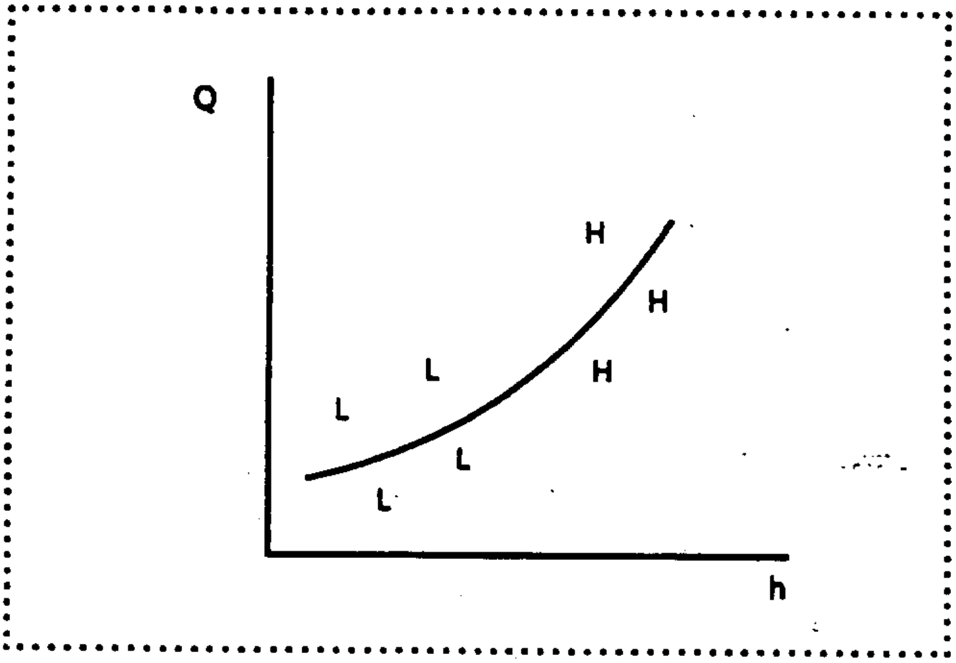
## II. Progress

The network of water level monitoring stations which would provide the basic data needed to develop a water budget for the lower C-111 canal system between S-18C and S-197 was set up. The installation of the network was completed during December 1988 and January 1989 (see Phase I progress report). The Phase I progress report, the first deliverable, and the Phase II interim progress report, the second deliverable, have been received. It is pointed out that the ground elevations in the

54 cutouts on the south side of the lower C-111 canal were surveyed and detailed discharge measurement sites were set up in selected cutouts. Two discharge sites were established to measure flows within the C-111 canal.

## III. Problems

A hypothetical rating curve showing discharge versus canal stage is shown in the figure below




*Q = discharge through downstream structure*
*L = discharge measurement at lower headwater stage*
*H = discharge measurement at higher headwater stage*
*h = headwater storage of downstream structure*

To develop a rating curve for a structure or any opening, discharge measurements must be made for a wide range of stages in the canal upstream. Due to lack of rainfall and consistently low water levels at S-18C, no valid discharge measurements through the culverts or the cutouts along the lower C-111 canal between S-18C and S-197 have been taken to date.

The controlled releases through S-18C are not enough to give a full range of measurements for developing rating curves for discharge through the cutouts. Any proposed experimental releases would yield measurements for low-flow conditions and thus caputure events for the low end of the rating curve designated by "*L*" in the above figure. No storm events have occurred during the study period to take any measurements for high flow conditions.

## IV. Proposed Solutions to Problems

A. The Operations Support Division of the Operations and Maintenence Department should advise Bob Johnson of the manual operation of S-18C in accordance with the minimum delivery schedule and/or the operation of S-331 pump station. This needs to be done so that ENP can coordinate their discharge measurements with the dates of the manual gate openings.

B Because of the lack of rainfall and low flow conditions, it is recommended, in the best interest of the District and ENP, that a no cost extension of the contract through part of the 1990 wet season (at least through August 1990) to capture high flow measurements for a sufficient number of events be approved. This is agreeable to Bob Johnson, ENP, and Robert Fennema, FIU.

The consequences of not granting an extension are having no stage-discharge relationships developed for the selected cutouts and having no water budget computed for the lower C-111 basin.

The above are the most useful products of this contract for future modeling efforts and better understanding of the effects of different management options upstream on the eastern panhandle basin.

If the extension is granted, it is requested that certain cutouts be cleared with help from the Miami Field Station to measure flow through the cutouts with and without vegetation to get an idea of the variation of flow with roughness. Comments concerning the no cost extension and the clearing of cutouts are welcomed and should be submitted to me by December 15, 1989.



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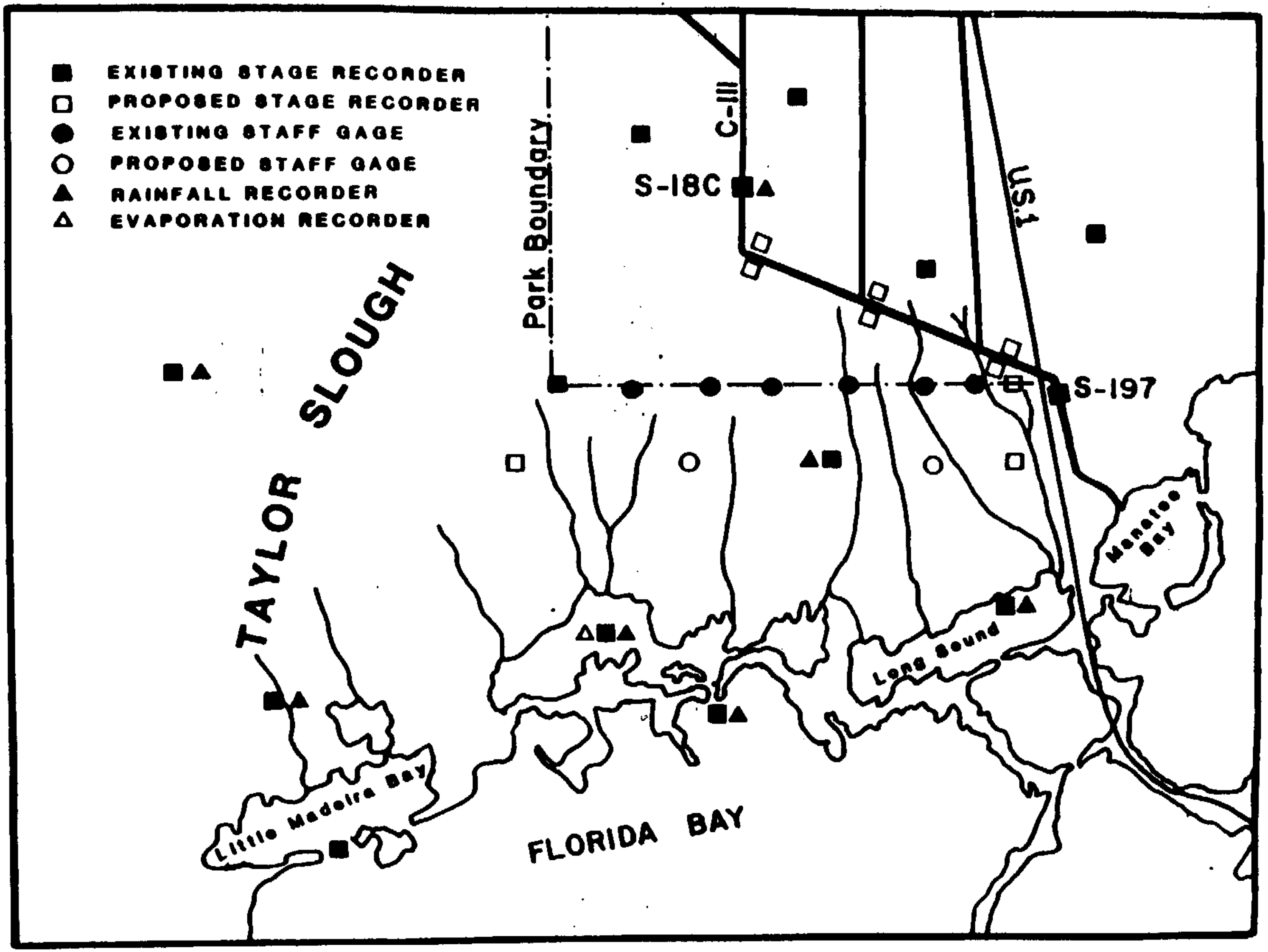


Figure 1. Base map of the lower C-111 canal system and the Eastern Panhandle area of Everglades National Park.

Appendix 6. Wading Bird Study for C-111 basin.

C89-0032

MU 5280-9-8004

# MEMORANDUM OF UNDERSTANDING
BETWEEN

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

AND

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
EVERGLADES NATIONAL PARK

This Agreement is entered into on April 12, 1989 between the South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, Florida, a public corporation of the State of Florida (DISTRICT) and the United States Department of the Interior, Everglades National Park, Post Office Box 279, Homestead, Florida 33030 (ENP).

WITNESSETH:

WHEREAS, the DISTRICT is empowered to enter into contractual arrangements with public agencies, private corporations or other persons pursuant to Section 373.083, Florida Statutes; and

WHEREAS, the DISTRICT and ENP have a mutual interest in conducting a study to determine the relationships between hydrological conditions and the quality and quantity of feeding habitat for Roseate Spoonbills and other wading birds in the C-111 Basin; and

WHEREAS, ENP has submitted a research proposal and has offered to conduct such a study; and

WHEREAS, the DISTRICT wishes to accept the proposal in accordance with the terms and conditions set forth herein.

NOW THEREFORE, in consideration of the mutual benefits flowing from each to the other, the parties agree as follows:

1. Unless extended or terminated, the period of performance of this Agreement shall commence on the date of execution and continue for a period of four (4) fiscal years terminating on September 30, 1992.

2. The purpose of this research project is to examine the relationships between Roseate Spoonbill foraging habitat use, breeding success and surface water conditions in the C-111 Basin. The work to be performed shall be in accordance with proposal "Relationships between hydrological conditions and the quality and quantity of feeding habitat for Roseate Spoonbills and other wading birds in the C-111 Basin", Exhibit A, attached and made a part of this Agreement. The work shall be performed by the National Audubon Society (NAS) by way of a Cooperative Agreement between ENP and NAS.

3. The amount expended under this agreement for the DISTRICT'S fiscal year 1988/89 ending September 30, 1989 shall not exceed $55,000.00. Payment of funds shall be made semi-annually upon receipt and acceptance of a six month progress report and twelve month annual report. Further funding of this agreement, up to a total of $185,500.00 ($55,000 each for FY 89,90 and 91 and $20,500 for FY 92) is subject to DISTRICT Governing Board budgeting for the following DISTRICT fiscal years. In the event the DISTRICT does not approve funding for future fiscal years, this Agreement shall terminate at the end of the then current fiscal year, notwithstanding other provisions in this Agreement to the contrary. The DISTRICT shall notify ENP after adoption of the final DISTRICT budget for each subsequent fiscal year as to the status of the funding for this Agreement.

4. ENP shall be responsible for obtaining "in kind contribution" from the National Audubon Society in the amount of $55,125.00 during fiscal years 89,90 and 91 and $19,550.00 for FY 92 for a total of $184,925.00 for the four fiscal years ending September 30, 1992.

5. The Project Manager for the DISTRICT is Peter David and all correspondence and communications from ENP other than invoices and notices shall be directed to him. The Project Manager shall be responsible for overall coordination and oversight relating to the performance of this Agreement.

6. All notices to ENP under this Agreement shall be in writing and sent by certified mail to the United States Department of the Interior, Everglades National Park, Post Office Box 279, Homestead, Florida 33030, Attention: Contracting Officer. All notices to the DISTRICT under this Agreement shall be in writing and sent by certified mail to:

South Florida Water Management District
Attn: Division of Procurement and Contract Admin.
Post Office Box 24680
West Palm Beach, Florida 33416-4680

The ENP shall also provide a copy of the notices to the DISTRICT'S Project Manager. All notices required by this Agreement shall be considered delivered upon receipt. Either party may change its address by providing prior written notice to the other of any change of address.

7. All invoices submitted by ENP shall reference the DISTRICT'S Agreement Number C89-0032. ENP shall submit the invoices on a semi-annual basis to the District's Division of Procurement and Contract Administration. The DISTRICT shall pay the full amount of the invoice within thirty days of receipt and acceptance, provided ENP performed the work according to the terms and conditions of this Agreement. All invoice shall follow the same format as shown in Exhibit B, attached and made a part of this Agreement. Failure by ENP to follow these instructions shall result in an unavoidable delay of payment by the DISTRICT.

8. ENP is a Federal Agency and is not an employee or agent of the DISTRICT. Nothing in this Agreement shall be interpreted to establish any relationship other than that of a Federal Agency, between the DISTRICT and ENP, its employees, agents, subcontractors, or assigns, during or after the performance of this Agreement.

9. ENP shall not assign, delegate or otherwise transfer its rights and obligations as set forth in this Agreement without prior written consent of the DISTRICT.

10. ENP shall maintain the following insurance provisions on Federal employees throughout the term of this Agreement:

(A) Worker's Compensation Insurance: Shall be for Statutory limits as stipulated under applicable state and federal laws. The policy shall include Employer's Liability.

(B) Comprehensive General Liability and Business Auto Liability: Through a self insurance program for the limits and conditions equivalent to those established in the Federal Tort Claims Act, 28 U.S.C. 1346(b), 2672-80.

(C) Aircraft Liability Insurance: Coverage shall be provided for under the Federal Tort Claims Act, 28 U.S.C. 1346(b), 2672-80.

11. If either party fails to fulfill its obligations under this Agreement in a timely and proper manner, the other party shall have the right to terminate this Agreement by giving written notice of any deficiency and by allowing the party in default ten (10) calendar days from receipt of notice to correct the deficiency. If the defaulting party fails to correct the deficiency within this time, this Agreement shall terminate at the expiration of the ten (10) day time period.



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12. Either party may terminate this Agreement at any time upon thirty (30) days prior written notice to the other party. In the event of termination, the DISTRICT shall compensate ENP for all authorized work performed through the termination date.

13. ENP shall assure that no person shall, on the grounds of race, color, creed, national origin, handicap or sex be excluded from participation in, denied the benefits of, or otherwise subjected to discrimination in any activity under this Agreement. ENP shall take all measures necessary to effectuate these assurances.

14. ENP, its employees, cooperators or assigns, shall comply with all applicable federal, state and local laws and regulations relating to the performance of this Agreement. The DISTRICT undertakes no duty to ensure such compliance, but will attempt to advise ENP, upon request, as to any such laws of which it has present knowledge.

15. The laws of the State of Florida shall govern all aspects of this Agreement. In the event it is necessary for either party to initiate legal action regarding this Agreement, venue shall be in the Fifteenth Judicial Circuit for claims under state law and the Southern District of Florida for any claims which are justifiable in federal court.

16. This Agreement may be amended only with the written approval of the parties.

17. This Agreement states the entire understanding between the parties and supersedes any written or oral representations, statements, negotiations or agreements to the contrary. ENP recognizes that any representations, statements or negotiations made by DISTRICT staff do not suffice to legally bind the DISTRICT in a contractual relationship unless they have been reduced to writing, authorized and signed by an authorized DISTRICT representative. This agreement shall bind the parties, their assigns and successors in interest.



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The parties or their duly authorized representatives hereby execute this Agreement on the date written above.

TRW

SOUTH FLORIDA WATER MANAGEMENT DISTRICT, BY ITS GOVERNING BOARD

By: ______________________
Chairman

U.S. DEPARTMENT OF THE INTERIOR
EVERGLADES NATIONAL PARK

By: ______________________

Title: Superintendent

By: ______________________

Title: Contracting Officer



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**Relationships between hydrological conditions and the quality and quantity of feeding habitat for Roseate Spoonbills and other wading birds in the C-111 Basin**

John C. Ogden
South Florida Research Center
Everglades National Park
National Park Service

Robin Bjork and George V.N. Powell
Research Department
National Audubon Society

Revised 25 August 1988

EXHIBIT "A"

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## INTRODUCTION

The Roseate Spoonbill population in Florida nests primarily in Florida Bay and feeds during the breeding season in the euryhaline ecotone between the Everglades and the Bay. Surveys since the mid-1970's indicate that spoonbills nesting in south Florida have shown unexplained fluctuations in numbers, building to a peak of over 1200 pairs in 1978-79 and then declining to about 500 pairs in the 1980's (Fig. 1). Reproduction during this period has been poor (Fig. 2).

Aerial surveys documenting foraging habitat use by wading birds during the nesting season indicate that the spoonbills are dependent on the lower C-111 basin (the euryhaline zone from Madeira Bay to U.S.1) for much of their food resources. During peak breeding months, up to 75% of the spoonbill population forages within the C-111 basin. Thus, the timing and magnitude of water deliveries down the C-111 canal may have a significant impact on the quality of spoonbill foraging habitat.

Discharges through the C-111 canal have been increased during the last decade as part of the N.E. Shark River Slough Water Delivery Experiment. If increased water flow through the C-111 canal affects water levels and/or drying rates such that the downstream habitat is unsuitable for spoonbill foraging, then differences in reproductive parameters would be expected between birds that feed in the C-111 basin and birds that forage in other regions of the Bay. Data collected during the 1987-88 nesting season support this prediction. Spoonbills nesting in northeastern Florida Bay (adjacent to the C-111 basin) experienced only 50-60% success while birds nesting in the western bay experienced 98% success. The principal spoonbill colony, which is located in northeastern Florida Bay, declined from an average of 450 nests in the mid-late 1970's to 110 nests in 1988.

Our current knowledge of both the foraging habitat requirements of spoonbills and the impacts of C-111 canal operation on downstream conditions are poorly understood. Therefore, we propose to study the foraging habitat of Roseate Spoonbills in conjunction with hydrology monitoring at the foraging sites and reproductive success of major colonies. These data will enable us to identify feeding habitat requirements of spoonbills and assess the impact of the C-111 canal operation on this species. The information will ultimately assist us in determining the best water management program for this region. Furthermore, spoonbills are often associated with many other species of wading birds on their foraging grounds. By using the Roseate Spoonbill as an indicator species we will better identify suitable foraging habitat of other wading birds.

## PARTICIPATION

This proposal has been developed jointly by the Research Center, Everglades National Park (ENP), and the Research Department, National Audubon Society (NAS). The proposal has been reviewed and approved by the South Florida Wading Bird Working Group. ENP will assume the lead responsibility for the overall implementation and management of this study. The National Audubon Society will be a cooperator with ENP to conduct the aerial surveys and flight-line study. NAS will concurrently monitor nesting success by spoonbills in Florida Bay in all three years. Compilation of semi-annual and annual progress reports and a final study report will be a joint responsibility of ENP and NAS. The significant Audubon contribution to the study is shown in the proposed budget.

## OBJECTIVES

To examine the relationships between Roseate Spoonbill foraging habitat use, breeding success, and surface water conditions in the C-111 drainage basin. These data will be used in conjunction with surface water response models to be developed by Everglades National Park (proposal by Johnson & Fennema) to evaluate the impacts of C-111 canal operation on the Florida Bay spoonbill population.

## STUDY SITE

The Florida Bay spoonbill population forages primarily in the euryhaline zone between the Everglades and Florida Bay from the Cape Sable peninsula east to Turkey Point. To facilitate analysis, this area will be divided into 6 regions based on differing hydrology: 1) coastal Cape Sable to Flamingo; 2) interior Cape Sable; 3) south of West and Seven Palms Lakes from Flamingo to Madeira Bay; 4) north of West and Seven Palms Lakes, including Craighead Basin; 5) C-111 basin; and 6) U.S. 1 to Turkey Point. The western section, Cape Sable to Flamingo, is thought to be the primary foraging site of spoonbills that nest on Sandy Key in western Florida Bay. If this pattern ~~in~~ is confirmed by foraging-flight data (see #2 below), the western region will provide a control for comparing habitat use and breeding success of this subpopulation with spoonbills that feed in the C-111 basin and nest in northeastern Florida Bay.

## METHODS

The first year will focus on nesting success and foraging distribution patterns to provide a basis for a more detailed analyses of site hydrology and foraging site habitat characteristics during the following 2 years of study. Data will be analyzed and a final report prepared during the fourth year of the study.

1) Foraging Habitat: Habitat use will be determined by weekly systematic aerial surveys of the study area (described above) during the 6 month breeding season (October through March). Distribution of Roseate Spoonbills and other wading birds will be plotted precisely on 7.5 minute topographic quadrangles. These data will identify the location and types of foraging habitats used by spoonbills and other waders. The frequency of surveys will allow us to analyze the dynamics of site use and to correlate changes in foraging distribution with C-111 discharges and local rainfall.

While this study focuses on the Roseate Spoonbill, we will collect data on distribution of all wading bird species in the area. These data will allow us to identify other wading birds that depend heavily on the C-111 basin and their specific habitat requirements.

2) Foraging Flights: Fixed-wing aircraft will be used to follow adult spoonbills from breeding colonies to foraging sites. These data will allow us to establish the relative importance of the C-111 basin to each of the 3 major breeding colonies (Sandy, Tern and Porjoe Keys colonies) so we can assess the impact of the C-111 canal operation on reproductive success.

3) Monitoring Reproduction: The three largest spoonbill colonies in the Bay will be monitored by ground censuses at 4-6 day intervals to measure number of birds nesting, clutch size, and nest success (up to 25-day-old nestlings at which point they disperse within the vegetation and cannot be associated with a specific nest). Nestlings found dead will be collected and necropsied to determine cause of death. The Mayfield method (a calculation of nest survival which allows for rigorous statistical comparisons) will be used to quantify reproductive success. The high frequency of nest checks will allow us to associate periods of colony stress and failure with C-111 operations and climatic events. To assess potential effects of rainfall at the colony on reproductive success, rainfall recorders will be monitored at each major breeding colony. Other weather data will be obtained from Everglades National Park.

As with foraging habitat, the three colonies used by spoonbills are also major colonies for other wading birds. Therefore, we will also monitor reproduction of those species.

Water-level recorders will be established during the second and third years of the study at several primary foraging sites, and the data collected at these sites will be integrated with data from the existing hydrological monitoring network. Thus, water level fluctuations at key foraging sites can be correlated with upstream hydrology and the C-111 canal operations. Rainfall recorders will be set at these same foraging sites to monitor the effect of local precipitation on foraging habitat.

## SUMMARY

The correlation of hydrological stages with spoonbill reproductive success and foraging patterns will allow us to determine the optimal habitat conditions for spoonbill foraging. Relating hydrology at the foraging sites with operation of the C-111 canal will allow evaluation of the system for water management in the region to facilitate maintenance of a healthy Roseate Spoonbill population in south Florida.

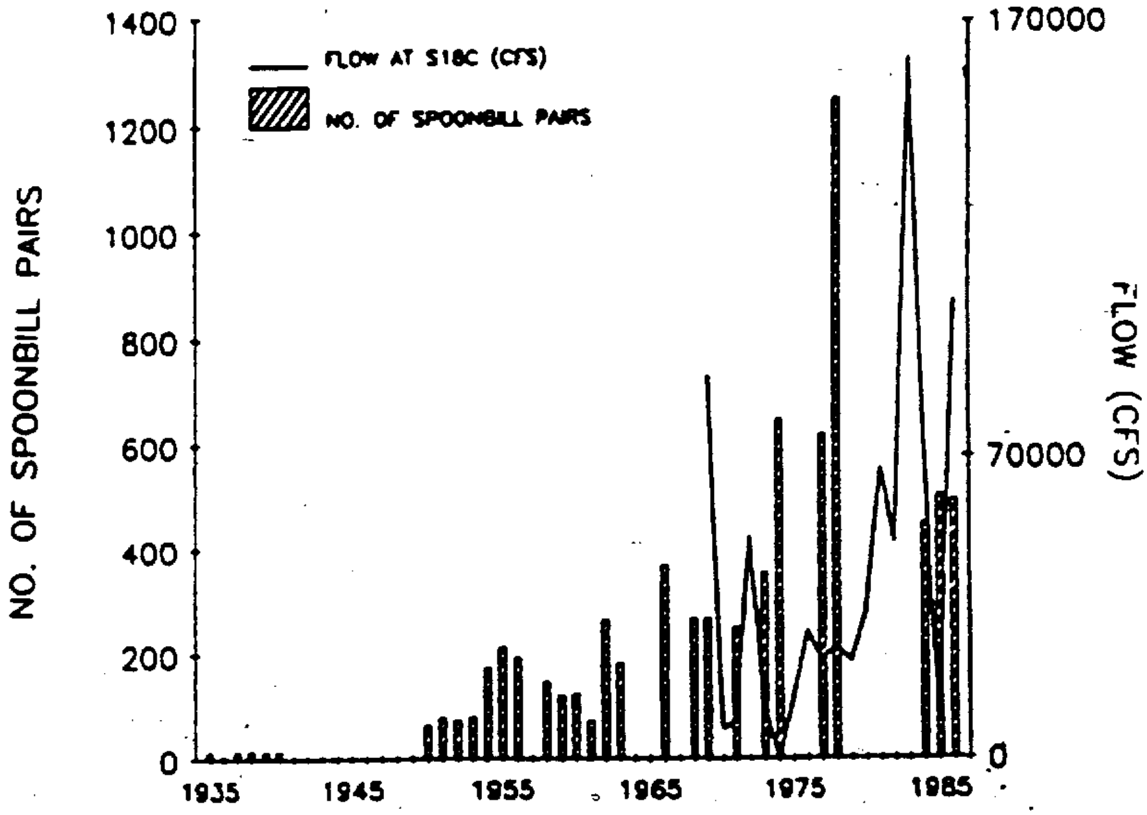


Figure 1. Total annual flow (cfs) through canal C111 (measured at S18C) and the total number of Roseate Spoonbill pairs nesting in Florida Bay from 1935-1986. Years without spoonbill numbers indicate that total counts were not available.

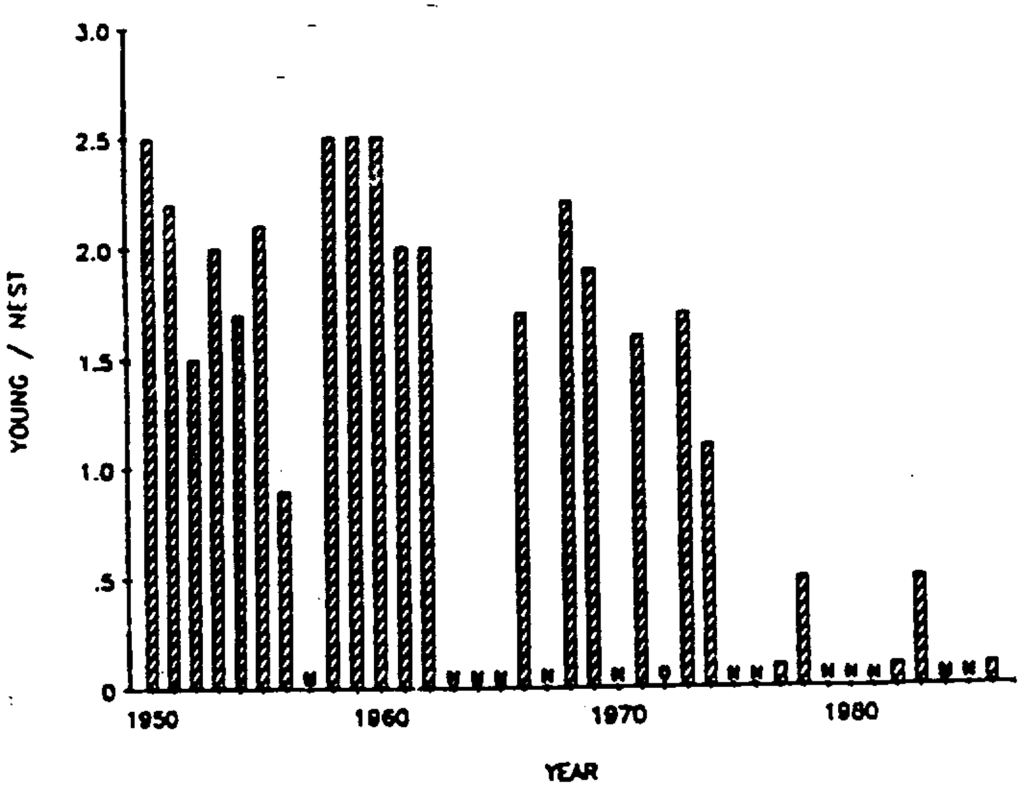


Figure 2. Estimates of reproductive success of Roseate Spoonbills in Florida Bay from 1950-1986. N indicates that no data were available and 0 indicates complete nesting failure.

## PROPOSED ANNUAL BUDGET FOR YEARS ONE-THREE
## (1988-89 TO 1990-91)

| | SFWMD | NAS |
|---|---|---|
| Fixed-wing Airplane Rental | $12,000 | $ 5,000 |
| Cessna 182: 120 hrs @~$120/hr | | |
| Cessna 172: 40 hrs @~$70/hr | | |
| Boat Use | $ 2,000 | $ 4,000 |
| Science Supplies | | $ 9,000 |
| Office Supplies | $ 1,000 | $ 1,675 |
| Auto Operations | | $ 2,150 |
| Stage/rainfall Recorders | | |
| Personnel: | | |
| P.I. (1/2) | | $12,500 |
| Biologist | $11,840 | $ 9,800 |
| Assistant | $18,500 | |
| Interns (2) | | $ 5,000 |
| Fringe Benefits | $ 8,160 | $ 6,000 |
| Publications | $ 1,500 | |
| TOTAL | $55,000 | $55,125 |

EXHIBIT "B"

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**PROPOSED BUDGET FOR YEAR FOUR**
**(1991-92)**

| | | SFWMD | NAS |
|---|---|---|---|
| Office Supplies | | $ 1,000 | $ 1,675 |
| Personnel: | | | |
| P.I. (1/2) | | | $12,500 |
| Biologist (2/3) | | $15,245 | |
| Fringe benefits | | $ 4,255 | $ 3,375 |
| Publications | | | $ 2,000 |
| | TOTAL | $20,500 | $19,550 |

EXHIBIT "B"

Appendix 7. Benthic productivity ENP Eastern Panhandle.



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# ASSESSMENT OF BENTHIC COMMUNITIES ALONG SALINITY GRADIENTS IN NORTHEASTERN FLORIDA BAY

by

Clay L. Montague, Richard D. Bartleson, and Janet A. Ley

Systems Ecology and Energy Analysis Program
Department of Environmental Engineering Sciences
University of Florida
Gainesville, Florida
32611

FINAL REPORT

to

The South Florida Research Center
Everglades National Park

in cooperation with

The South Florida Water Management District

University of Florida Cooperative Agreement
CA 5280-5-8004, Supplemental Agreement 4
Clay L. Montague, Principal Investigator

31 August 1989

1.4

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## ACKNOWLEDGMENTS

The catalyst who made our proposed study of benthos along salinity gradients in northeast Florida Bay a reality was Mr. Jim Tilmant of the South Florida Research Center, Everglades National Park, to whom we owe a debt of gratitude. Jim provided insight about the C-111 canal issue and northeast Florida Bay, provided essential equipment and support, and even participated in one of our field trips. Dr. Gary Hendrix, Director of the Research Center provided encouragement and facilitated the cooperative agreement between the University of Florida, the Everglades National Park, and the South Florida Water Management District. Mr. Ed Rutherford of the Research Center oriented us to the area, assisted us in our first field trip (March 1986), and collected salinity and current data for us in June 1986. Mr. Jim Milleson and Dr. Walt Dineen, our main contacts at the South Florida Water Management District, continue to support our efforts in understanding the management implications of altered freshwater flows in estuaries. Mr. Dan Haunert and Mr. David Swift, also of the Water Management District, provided insight into the biology and ecology of the area around C-111 canal. This research was supported by funds originating from the South Florida Water Management District and provided to the University of Florida by the Everglades National Park.

We are indebted to a total of 34 graduate and undergraduate student employees supported at various times by the project funds at the University of Florida. The following people participated with us in field data collection: J. Awong, J. Gottgens, J. Herrington, M. Marro, K. Merritt, D. Peterson, R. Ruble, and T. Toop. Processing of water chemistry samples was assisted by E. Catineau, I. Poyer, and F. Rowan, under the supervision of R. Bartleson. Processing of submerged vegetation and benthic fauna samples was initially managed by Mr. Richard Ruble, who developed the basic laboratory protocols, and later managed by J. Ley. These protocols were revised, refined and fully developed by Mr. Edgar Rivera, without whose efforts this project would not have been possible. The following people assisted Mr. Rivera, Mr. Ruble, and Ms. Ley in these efforts: J. Bernardo, R. Bryant, E. Catineau, D. Collins, P. Dasher, T. Dinh, L. Elliott, W. Evans, C. Flynn, M. Frias, D. Grove, J. Herrington, A. Jamieson, M. Kehoe, H. Marcone, M. Marro, M. Maturo, K. Merritt, J. Minneti, D. Peterson, M. Sack, M. Sawka, and W. Takken. Assistance in data entry on the computer was provided by L. Elliott, J. Fuller, K. Kilman, K. Merritt, D. Peterson, and R. Ruble. Office assistance was provided by J. Fuller and K. Kilman.

The Department of Environmental Engineering Sciences and the College of Engineering at the University of Florida provided invaluable assistance in the daily business of running a contract. In the department, we are especially appreciative of the energetic efforts of Ms. Eleanor Merritt in solving a profusion of complex budgetary matters and Ms. Eleanor Humphries in handling the multitude of personnel appointments. Ms. Berdenia Monroe helped to manage our accounts and keep us informed of our budget. Ms. Joanie Breeze applied her expert knowledge of university forms and protocol whenever an order was placed. We also thank Dr. Warren Viessman, Professor and Chairman for his enthusiastic support of the goals of our project. In the college, we are especially grateful to the untiring assistance of Ms. Jan Chitty, Grants Specialist, without whom is unimaginable.

The Center for Wetlands under the direction of Drs. H.T. Odum and G.R. Best provided a van for our field trips, and lent the assistance of Ms. Jenny Carter and her office staff in preparing the final report. The University of Florida Marine Laboratory at Seahorse Key, under the direction of Dr. Frank Maturo provided a boat for the early sampling trips.

# EXECUTIVE SUMMARY

Submerged vegetation and bottom-dwelling animals (benthic communities) were quantified together with aquatic system metabolism and a variety of environmental parameters at twelve stations along three salinity gradients in northeast Florida Bay, south of C-111 canal. Scheduled modifications to the canal will likely change the freshwater delivery to this region. Concern has been expressed about the potential impact this may have on a variety of fish and wildlife, especially commercially and recreationally valuable fishes that may use the region as habitat. Benthic communities are known to provide food and cover to a wide variety of juvenile and adult estuarine and marine fishes and shellfishes. The purpose of this assessment was to document the type and development of existing benthic communities and to provide information about how changes in salinity might affect changes in the benthic communities in this area. It was believed that repeatedly sampling at stations located along salinity gradients would meet these objectives.

Following a pilot study of five field trips to 21 stations (March through August 1986), 12 stations were selected for final study, four in each of three tributary-to-bay systems in northeast Florida Bay. Within each system, stations were selected to be as similar as possible in all respects except salinity. The salinity change from upstream to outer stations was similar among the three systems. The western system (Taylor River, Little Madeira Bay) is considered to be little influenced by the C-111 canal and



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therefore serves as a potential control for judging future effects of canal modifications. The central system (Snook Creek, Joe Bay, Trout Cove) and eastern system (Highway Creek, Long Sound, Little Blackwater Sound) are believed to be directly in the pathway of any influence of canal modifications. In the main study, stations were sampled using identical techniques every other month for 12 months beginning in August 1986 (through September 1987).

Benthic community development and metabolism were very low in general. Overall gross primary production was only 188 g-C/m²/yr. Gross primary production at outer stations, however, was three times higher than at upstream stations. The planktonic portion of this production was very low at all stations, but was twice as high at upstream stations, where it accounted for 44% of the gross production (as opposed to only 7% at outer stations). Benthic communities at outer stations, although low in production and biomass compared to other Florida Bay seagrass-dominated communities, had roughly 50 times more numbers of animals and biomass of plants than upstream stations. Plants at outer stations were dominated by turtlegrass (<u>Thalassia testudinum</u>) and calcareous green macroalgae (primarily <u>Penicillus</u> and <u>Udotea</u>). The few plants at the upstream stations consisted mostly of shoalgrass (<u>Halodule wrightii</u>), widgeongrass (<u>Ruppia maritima</u>), and the green macroalgae <u>Chara</u>. Roughly 95% of all animals collected at each station were polychaetes, peracaridean crustaceans (amphipods, isopods, and tanaids), and bivalve mollusks.

Variation in salinity that includes frequent changes from freshwater to marine conditions is believed to account for the depauperate benthic communities at upstream stations. Upstream stations had both lower mean salinity and much more variable salinity than outer stations. Many other environmental conditions did not systematically vary from upstream to outer stations, owing in part to careful selection of stations. These included average water depth, average water-level fluctuation, sediment thickness, sediment organic content and sediment particle size. Weather and water temperature, light extinction, pH, biochemical oxygen demand (BOD), ortho-phosphate concentration, morning dissolved oxygen, and plankton metabolism also did not vary significantly from upstream to downstream. Some parameters did vary systematically from outer to upstream stations. These include daily change in dissolved oxygen concentration, dissolved oxygen level in the afternoon, and total open-water oxygen metabolism (all lower upstream), total nitrogen, total phosphorus, and ammonium concentrations (all higher upstream), variation in total nitrogen and ammonium concentrations (higher upstream), total suspended solids (lower upstream), and bottom water temperature (slightly higher upstream). Some of these tendencies, however, could be partially or wholly explained by the lack of vegetation, which if present would increase oxygen and decrease nutrient concentrations.

Some environmental differences were noticed among the three systems (western, central, and eastern). The eastern system tributary (Highway Creek) was lower in salinity and higher in upstream discharge of water. Differences in benthic community development and degree of salinity fluctuation between upstream and outer stations were greatest in the western system, perhaps resulting from a lower discharge of freshwater in that system. It seems apparent that the US Highway 1 causeway (together with the routine plugging of the C-111 canal) accounts for the greater flow of water in the eastern system by blocking an apparently historical water flow more to the east (as judged by the northwest-to-southeast orientation of tree "islands" in the marshes on each side of the highway).

Phosphorus appears to be in very short supply compared to nitrogen in the water at our stations. In nature an atom-based nitrogen-to-phosphorus ratio of 16:1 is often used for comparison. The waters of our stations have an average ratio of over 300:1, indicating the likelihood of severe phosphorus limitation. No indication of significant supplies of nitrogen or phosphorus from inflowing waters was found, though our study was not designed with this objective in mind and did not include all necessary measurements for a definitive conclusion about nutrient transport in freshwater flow into northeast Florida Bay. Salinity fluctuation is apparently much more influential on benthic community development than are nutrients at our stations. Addition of nutrients would undoubtedly increase primary production at our stations, but the form of this production is difficult to predict. It could be benthic bluegreen algae (e.g. _Lyngbya_), benthic diatoms, planktonic microalgae, or submerged vegetation, such as seagrasses and macroalgae.

## Suggested Future Research

Several studies of relevance to C-111 canal management have been identified in the course of this research and the analysis of the resulting data. First, because the focus on benthic studies related to their potential value as fish habitat, a study of fish use of this region seems essential prior to canal modifications. Use of mangrove prop-roots by fishes is evident in the area. Inclusion of this habitat as well as the benthic habitat is important. Such a study is presently being funded by the South

Florida Water Management District and has been contributed to further by Florida Sea Grant. The potential for nutrients to be supplied to northeast Florida Bay by C-111 canal should be addressed, but not without studies of the supply and demand for nutrients in northeast Florida Bay ecosystems. Additional monitoring of some aspects of the benthic community prior to canal modifications is advisable because of the great temporal and "random" variability found, which could make detection of an effect of canal modifications difficult to distinguish from natural variation. The benthic and planktonic microbial communities are evidently of importance in ecosystem metabolism at upstream sites. Special studies of these communities will provide a more complete picture of present conditions at upstream stations.

Finally, and most importantly, is the possibility of developing a management principle that can be applied in the adjustments of C-111 canal and in canal modifications elsewhere in south Florida and beyond. Controlling salinity fluctuation is perhaps the key to controlling impact on estuarine animals and plants. Experiments and specific field observations to test and separate the various influences of the frequency, amplitude, suddenness, and seasonal timing of salinity fluctuations will directly lead to an ecologically sound principle of freshwater flow management in estuaries. Such a management principle should have frequent and wide application. If developed, it should allow engineers to consider impact at the design phase of canals and canal modifications. This should then reduce the expense of trial-and-error monitoring programs designed to evaluate impact on a case-by-case basis, after the fact. When such a principle is proven to work, it will eliminate the need for some kinds of impact-assessment monitoring.

## INTRODUCTION

C-111 canal, south of Homestead, Florida, exists primarily because of desired cropland drainage and flood control in the upper drainage basin west of Florida City and Homestead, Florida. Water from C-111 canal drains into tributaries of northeast Florida Bay, through the eastern-most part of the Everglades National Park. Of primary concern in the management of this lower basin are the effects of freshwater delivery from the canal on Park fish and wildlife that live within the lower basin and northeast Florida Bay, within the zone of influence of canal discharges. Modifications of C-111 canal have been proposed to allow better flood control in the upper basin and more flexibility for environmental management of the lower basin. Adequate knowledge of the effects of these modifications is essential for developing an environmental management plan, but is presently unavailable. A point of particular concern is the effect of salinity changes caused by canal modifications on the quality and use of fish habitat, particularly regarding species of commercial and recreational importance.

Bottom communities, consisting of seagrasses and various invertebrate animals are of considerable importance as fish habitat, not only in Florida Bay, but also in many of the world's estuaries and coastal bays (Zieman 1982, Schomer and Drew 1982, Durako, et al. 1987). Seagrasses provide protection from predators (cover) for early juvenile stages of fish. Bottom-dwelling (benthic) invertebrates -- both in bare mud and associated with seagrasses -

- are important foods of fish. Salinity is an especially important factor in the survival of aquatic animals and plants. Changes in salinity undoubtedly cause changes in the types and abundances of organisms. Each individual has a range of salinity tolerance and a narrower range of optimal salinity (Remane and Schlieper 1971). Vagile organisms may leave when conditions become unfavorable. Sedentary benthic animals and plants must either tolerate the changes or die. For those that survive a salinity change, growth may be retarded, unaffected, or enhanced. An understanding of the response of the living components of fish habitat to changes caused by canal modifications should lead to better management of fishery resources in northeast Florida Bay, especially when coupled with a similar level of understanding about local fish use of this habitat, and the hydrological impact of the canal.

In March 1986 an assessment of benthic animals and plants was begun in several tributaries and near-shore bays of northeast Florida Bay in the area south and west of C-111 canal. The purpose was to provide a baseline of ecological information about estuarine habitat which could be compared to the same sites after canal modifications. In the process, an attempt was made to gain insight into the types of effects to be expected if future canal modifications alter freshwater delivery to northeast Florida Bay and hence salinity (a likely occurrence). The long-term goal begun with this research is to develop management principles that address ecological impact in estuaries. Upon development, such principles of estuarine impact not only can be applied in post-construction freshwater flow adjustments, but also -- and most importantly -- can be applied in the design phase of future canal modifications in south Florida and elsewhere.



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# MATERIALS AND METHODS

## Study Site

The northern shore of eastern Florida Bay consists of a series of semi-enclosed shallow bays bordered by mangroves. Narrow outlets connect these bays to Florida Bay. A series of small tributaries (generally 10 to 20 m wide) drain the southeastern part of Everglades National Park and adjacent lands to the north. These open into the northern shores of the shallow bays. Many of these tributaries contain a series of small (2 to 5 ha), very shallow (50 to 120 cm) ponds connected by deeper stream runs. The bottoms of the ponds contain a layer of calcium carbonate marl 30 to 100 cm thick which overlies hard calcium carbonate rock. The stream runs contain little or no bottom sediment.

Drainage from the C-111 canal generally flows toward northeast Florida Bay to the west of US Highway 1, except during periods of upstream flooding (and high canal discharge). At such times, a plug may be opened that allows water to rapidly flow to Barnes Sound on the east side of US Highway 1. When the canal is plugged, flow to the east is blocked by the US Highway 1 causeway. Water from the canal drains through a series of openings carved into the south canal bank and joins water from the drainage basin north of the canal. This water flows toward northeast Florida Bay over marsh and into a series of small tributaries.

The 200 km$^2$ study region (Figure 1) extends from Little Madeira Bay east to US Highway 1, within a rectangle from 25°10'N, 80°40'W at the southwest corner to 25°15'N, 80°25'W at the northeast. Samples were collected from stations within three tributary-to-bay systems: Taylor River--Little Madeira Bay (western system), Snook Creek--Joe Bay--Trout Cove (central system), and "Highway Creek"--Long Sound--Little Blackwater Sound (eastern system). The eastern and central systems are south of the C-111 canal and are believed to be influenced by canal drainage. In addition, the eastern system, which includes the creek closest to US Highway 1 ("Highway Creek"), is also apparently influenced by the US 1 causeway, since water cannot cross the causeway when the canal is plugged. The western system is west of the canal and is believed to be outside of the area of influence of canal drainage.

## Pilot Study

From March 1986 through September 1986, a pilot-study was performed to develop techniques and select sampling stations for periodic collections of benthic animals and plants, and certain water quality and physical parameters during the following year. Laboratory analyses as well as field sampling techniques were developed. Pilot-study field trips were made during March, April, May, July, and August. A total of 21 alternative stations were sampled in each of the three tributary-near-shore bay systems using a variety of techniques. The stations and techniques identified and detailed below are those found to be most effective for use during the main study. Results reported for the pilot-study period sometimes used slightly different

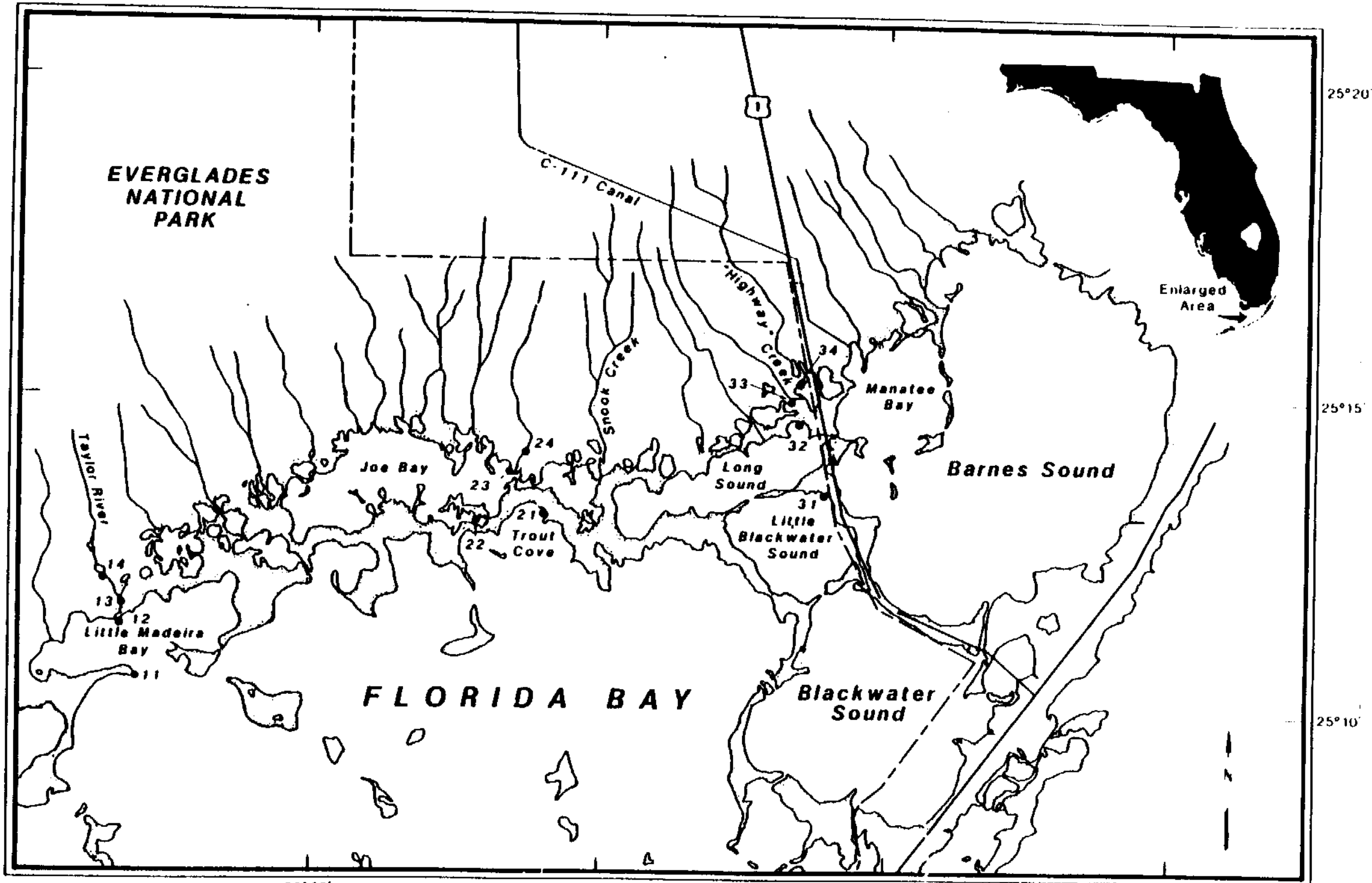


Figure 1. Study Region in Northeastern Florida Bay with Station Numbers Indicated.

techniques or were collected at different sampling stations than used during the main study. These differences will be clarified as needed.

Stations for the main study were to be as similar as possible in every physical respect except mean salinity. In order to help with this decision, stations visited during the pilot study were characterized with respect to water depth, pH, current, salinity, sediment depth and sediment particle size, organic content (measured as dry weight lost on ignition), and calcium carbonate content (measured as dry weight lost on dissolution with 50% hydrochloric acid).

## Main Study Sampling Stations and Sampling Frequency

Within each of the three tributary-nearshore bay systems, four stations were located along a salinity gradient from generally marine conditions in the nearshore bays to lower salinities within a tributary. The stations and a numerical code used in this report are given in Table 1. In the western system the highest salinity (and most bayward) station was in the vicinity of the National Park Service's hydrostation at the entrance to Little Madeira Bay (LMBHS or Station 11). The next highest salinity station was in Little Madeira Bay just off the mouth of Taylor River (LMBTR or Station 12). Two stations of progressively lower salinity were chosen in Taylor River: the first pond encountered on the way upstream (TRPD1 or Station 13) and the third pond (TRPD3 or Station 14). Corresponding stations of the central system included (from highest to lowest salinity): 21) the northeast corner of Trout Cove (NETCV); 22) the first small bay (or large pond) encountered along Trout Creek when heading north towards Joe Bay (called "Little Joe Bayou," LTLJB); 23) the northeast corner of Joe Bay just off the mouth of



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Table 1. Stations and stream runs sampled in the main study with numerical codes and acronyms used in this report.

STATIONS

Western System:

| Code | Acronym | Station Description |
|---|---|---|
| 11 | LMBHS | Mouth of Little Madeira Bay near Hydrostation |
| 12 | LMBTR | Little Madeira Bay near mouth of Taylor River |
| 13 | TRPD1 | First pond encountered up Taylor River |
| 14 | TRPD3 | Third pond encountered up Taylor River |

Central System:

| Code | Acronym | Station Description |
|---|---|---|
| 21 | NETCV | Northeast corner of Trout Cove |
| 22 | LTLJB | "Little Joe Bayou" (large pond up Trout Creek) |
| 23 | NEJBY | Northeast corner of Joe Bay near Snook Creek |
| 24 | SCPD3 | Third pond encountered up Snook Creek |

Eastern System:

| Code | Acronym | Station Description |
|---|---|---|
| 31 | NELBS | Northeast corner of Little Blackwater Sound |
| 32 | NELSD | Northeast corner of Long Sound |
| 33 | HCPD1 | First pond encountered up Highway Creek* |
| 34 | NWHP2 | Northwest corner of second pond up Highway Creek |

STREAM RUNS

Western System:

| Acronym | Stream Run Description |
|---|---|
| TRRN1 | Taylor River between mouth and first pond |
| TRRN2W | Taylor River between first and second ponds (west branch) |
| TRRN3 | Taylor River between second and third ponds |

Central System:

| Acronym | Stream Run Description |
|---|---|
| TCRN1 | Trout Creek between mouth and large first pond |
| JBYRN | Trout Creek between large pond and Joe Bay |
| SCRN1 | Snook Creek between mouth and first pond |
| SCRN2 | Snook Creek between first and second ponds |

Eastern System:

| Acronym | Stream Run Description |
|---|---|
| HCRN1 | Highway Creek* between mouth and first pond |
| HCRN2 | Highway Crrek between first and second ponds |

* "Highway Creek" is the name used for the creek closest to the west side of US Highway 1 (mouth empties into northeastern Long Sound).

Snook Creek (NEJBY); and 24) the third pond encountered up Snook Creek (SCPD3).

Stations of the eastern system were: 31) the northeast corner of Little Blackwater Sound (NELBS); 32) the northeast corner of Long Sound just off the mouth of Highway Creek (NELSD); 33) the east side of the first pond encountered up Highway Creek (HCPD1); and 34) the northwest section of the second pond encountered on the eastern branch of Highway Creek (NWHP2).

Samples were collected every other month at approximately the same place within each of the 12 stations, to obtain a profile of seasonal fluctuations in benthos and environmental variables. Main-study field trips occurred in November 1986 and in January, March, May, July, and September 1987. Each one-day visit to a station was within 100 m of the other visits at that station and was always in water of similar depth (50 to 100 cm). The logistics of this study required that samples of vegetation, sediment, and water be returned to Gainesville, Florida for analysis. Other measurements were taken in the field.

## Submerged Vegetation Sampling and Analysis

Vegetation was sampled with core and surface samplers within an area of roughly 150 $m^2$ around the boat. Core samplers were necessary for sampling roots and rhizomes in dense sediments containing turtlegrass (*Thalassia testudinum*) or mats of other rhizomatous seagrasses. Below-ground material could be adequately sampled with surface samplers in loose sediment without dense rhizomes. Both types of sampling device adequately sampled aboveground material.



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Core samplers were made with a 35 cm length of 15 cm diameter PVC pipe, beveled on one end and capped on the other. The capped end contained a hole for a small rubber stopper, a stopper on a string, and a rope handle. The coring tube was inserted to 30 cm with the cap-hole open. After insertion of the tube, the cap-hole was stoppered, which created a vacuum upon core removal. Suction below the core was released by gently rocking the coring tube while pulling up on the handle. On each field trip and at each of the 12 stations, five sediment cores were removed. Each was gently washed through a 5 mm mesh bucket sieve. All material remaining on the sieve was placed in labeled plastic bags and stored on ice until analyzed.

Surface samplers were each made from the top half of a 200 l plastic pickle barrel with a wide-mouth screw top. Each resulting dome sampler covered approximately 0.25 $m^2$. With the tops removed, vegetation could be hand picked from within the dome. The protection from the surrounding current afforded by the domes allowed samples of vegetation to be collected and placed in storage bags with negligible loss. On each trip and at each station two surface samples were collected by this method in addition to the five core samples. Sampled material was stored in labeled plastic bags on ice until analyzed.

## Vegetation Analysis

Vegetation samples were sorted by species, and separated into live at time of collection, dead at time of collection, and detritus categories. Green plant tissue was considered live. Unattached, well-decomposed (very fragile), generally black or dark brown tissue was considered detritus. Brown tissue that was not well-decomposed was considered dead. Live and dead tissue was further sub-divided into above and below-ground portions. Roots, rhizomes, and the bases of shoots were considered below ground for all seagrasses. Holdfasts of macroalgae were also put in the below-ground category. August 1987 samples were not sorted because of technical difficulties that led to a fear that the samples would deteriorate if not analyzed quickly.

In the laboratory, it was often difficult to distinguish between Ruppia and Halodule in samples because of poor growth and development of identification features at many stations (primarily leaf shape and to a lesser degree rhizome characteristics). Leaves and rhizomes of these plants are easily distinguished under good growth conditions. When a decision could not be made, plants were put in a "Rup/Hal" category.

Once sorted, vegetation was dried and weighed. A large number of dried and weighed samples were also combusted at 450°C and re-weighed to determine percent ash (an estimate of the proportion of inorganic matter in the vegetation). Dry and ash weights for each category and each replicate of each sampling device were entered into the LOTUS 1-2-3 spreadsheet program for subsequent data reduction via micro-computer.

## Benthic Macrofauna Sampling and Analysis

Benthic animals were sampled several ways at each station and on each trip in order to assess separate portions of the animal community. During the pilot study, the importance of epifauna associated with the leaves and stems of submerged vegetation (seagrasses and macroalgae) became apparent. Pilot study results also indicated that nearly all of the small infauna (those passing a 5 mm sieve) occurred within the top 10 cm of the surface.

Epifauna, small shallow infauna, and larger infauna are likely to be the most common foods for fish. Accordingly, larger infauna were collected in the same five 15 cm diameter cores to 30 cm depth used for sampling vegetation (described above). Fauna retained on the 5 mm sieve were placed in a labeled plastic bag and stored on ice until analysis.

Smaller infauna and epifauna (those that pass through a 5 mm sieve) were sampled by removing 10 smaller cores (10 cm diameter, 10 cm depth) using a smaller but otherwise similar coring tube. The tube was 35 cm long but was inserted only 10 cm to prevent loss of epifauna through the hole in the cap as the core is inserted, while still collecting the shallow infauna. Each shallow core was sieved through a 503 um mesh bucket sieve. Material remaining on the sieve was placed into a labeled plastic jar. Samples were covered with a 4% buffered formalin solution made with seawater, to which the protein stain rose bengal had been added. Samples were stored this way until analysis.

Epifauna were also sampled without including small infauna, by inverting a 363 um mesh, 20 cm diameter plankton net over the top of representative samples of vegetation. The sample in the net was transferred to a 503 um bucket sieve and subsequently treated like the samples from the smaller cores above. The vegetation in the sample was sorted, dried, and weighed as described in the section on vegetation.

Plants removed from the dome samplers described in the section on vegetation were also examined for associated fauna.

## Analysis of Benthic Macrofauna

Material collected in the inverted plankton nets and shallow core samples was re-sieved in the laboratory through a 2 mm screen. Material passing through the screen was saved for later analysis. Material retained on the screen was analyzed. In 10% of the shallow core samples, material retained on a 1 mm screen was also analyzed for comparison. Fauna from all sampling devices were sorted by class (where preservation techniques allowed) and by size (< 1.0 cm, 1.0 to 2.5 cm, and > 2.5 cm in length) and stored on 95% isopropyl alcohol in labeled vials. Vegetation collected with the fauna was sorted, dried, and weighed as described previously. Numbers of individuals in each size and type category for each replicate of each sampling device were entered into the LOTUS 1-2-3 spreadsheet program for subsequent data reduction via micro-computer. Results were expressed in numbers per $m^2$. Numbers of epifauna collected in the inverted plankton nets were first expressed per gram of dry vegetation and then multiplied by the average dry weight of vegetation per $m^2$ in order to express results on an aerial basis.

## Water Quality and Other Environmental Parameters

Salinity, water temperature, conductivity, and oxygen were measured with calibrated electronic instruments twice (morning and afternoon) during each visit to a station. A YSI Model 33 S-C-T meter and two YSI Model 57 oxygen meters were used for each measurement. Each function on each meter was calibrated using two standards prior to each field trip. In addition, the oxygen meters were air-calibrated immediately before each field measurement. Because electronic oxygen meters often drift out of calibration



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during field use, two meters were used simultaneously. If the readings did not agree within 0.2 mg/l, the problem was identified and fixed, and the measurements repeated. Apparent oxygen readings were corrected for salinity using the equations given by Pijanowski (1973). The salinity adjustment knob on the oxygen meters was set to zero to reduce meter to meter differences caused by the extra circuitry.

During each measurement period, measurements were made 10 to 20 cm below the surface and 10 to 20 cm above the bottom to detect stratification. Along with these measurements other data were collected, including time of day, water depth, barometric pressure, dry bulb and wet bulb air temperature, wind speed, and wind direction. Cloud cover and occurrence of rain was also noted.

At mid-day, light (photosynthetically active radiation: 400 to 700 nm wavelength) was measured with a calibrated photocell just above the water surface, just beneath the surface, and at a known depth near the bottom, so that extinction coefficients could be calculated. Also at mid-day, pH was measured and duplicate samples were taken for nutrient analyses, biochemical oxygen demand (BOD), and total suspended solids (TSS). If the earlier measures of salinity and temperature indicated stratification, then samples were collected from both the upper and the lower layer of water. If not, samples were collected at arm's length.

During the pilot study, pH was measured using a field-calibrated pH meter and was found to always be slightly basic and to vary little. Field calibration of the meter was very time consuming because of considerable meter drift, especially during very hot weather. For the final study, pH was monitored only with pH paper in order to document any sudden drop in pH that might occur because of the possible appearance of acid swamp waters from upstream following a rain storm.

### Run Currents and Discharge

Currents were measured in the runs (streams) between ponds and between the mouth and the first pond of each of the three tributaries (Taylor River, Snook Creek/Trout Creek, and Highway Creek) at one point during most of the sampling trips. Stream runs that were sampled are indicated in Table 1. Currents were measured by timing the movement of a current cross drogue for a known distance (usually 1 to 3 m). Triplicate measures were made at each stop. The direction of flow (flood or ebb) was noted. Channel depth was estimated by placing a depth stick three times near the center of the channel at the site chosen for current measurement. During the pilot study, current measurement stations were established and marked with surveyor's tape so that the same points could be revisited on subsequent field trips. Stream width and bottom topography were determined at each of these sites. Average discharge was estimated from average current times average cross-sectional area by using the depth-dependent discharge coefficients for rod floats given in USDI (1984).

### Nutrient Sample Preservation and Analyses

Water samples for dissolved nutrients (ammonium and orthophosphate) were filtered through a Whatman 934-AH glass fiber filter (effective retention of 1.5 um), preserved with sulfuric acid (1 ml concentrated acid per liter of sample), and stored on ice until analysis the following week. Ammonium was analyzed by the salicylate-hypochlorite method of Bower and

Holm-Hansen (1980). Orthophosphate was measured by the ascorbic acid method given in Standard Methods, 14th Edition.

Water samples for total nutrients were left unfiltered, but were preserved with acid and stored on ice until analysis. Total nitrogen was analyzed by the following modification of the method developed by Koroleff (1970). Nitrogen was oxidized to nitrate with persulfate and reduced to nitrite with zinc. The nitrite was then analyzed following the methods given in Parsons et al. (1984). Total phosphate was analyzed with the persulfate digestion and ascorbic acid procedures given in Standard Methods, 14th Edition.

## BOD Sample Preservation and Analysis

Water samples were collected in labeled 300 ml BOD bottles and stored on ice until the evening following collection. At that time the samples were warmed to 20 to 25°C and gently bubbled for 15 min to insure initial equilibration with air. Immediately following equilibration, dissolved oxygen was measured with a calibrated YSI Model 57 oxygen meter fitted with a stirring BOD electrode. Salinity corrections were made by later computation, as before. After initial measurement, the bottles were capped and stored at room temperature in coolers (to reduce temperature fluctuations in transit). After storage for five days, samples were removed from the coolers, and dissolved oxygen was measured again. BOD is the salinity-corrected difference between the initial and the five-day measurement for each bottle.

### TSS Sample Preservation and Analysis

A known volume of water (generally 1000 ml) was filtered through a pre-weighed and pre-muffled Whatman 934-AH glass fiber filter using a hand-operated vacuum pump. The filter was rinsed with distilled water to remove salt and was placed in a plastic filter-holder and stored on ice until it could be transferred to a freezer for storage until analysis. Filters were then dried and weighed to determine TSS (after subtracting the initial filter weight), and then muffled at 450°C and re-weighed to determine percent organic matter.

## Oxygen Metabolism

In an effort to measure a rate of activity in conjunction with the standing accumulations of benthic animals and plants, oxygen change over time was measured several ways at each station. Oxygen increases in the light when photosynthesis exceeds respiration. The rate of oxygen increase in the light is called net community production (NCP). In the dark, no photosynthesis occurs, so oxygen decreases. The rate of oxygen decrease in the dark is called community respiration (CR). Community respiration is often assumed to be nearly the same in the light as well as in the dark, so an estimate of gross primary production (GPP) is obtained by adding NCP and CR together.

Net community production of the entire submerged aquatic community can be estimated by monitoring daytime oxygen change in open water, and correcting for diffusion of oxygen to and from the air (Odum and Hoskin 1958, McKellar 1975). The correction for diffusion is not required in the lower layer of stratified water. Aquatic community respiration can likewise be measured at night, or can be measured in opaque domes placed over the bottom.



1C a

During the pilot study, oxygen was tracked around the clock at two stations on each of the first four trips (March, April, May, and July 1986). An upstream and an outer station were monitored in a different system on each trip. This method, however, was considered too labor intensive and therefore not cost effective for the final study. In the main study, community respiration was estimated by monitoring oxygen uptake in opaque domes (see below).

Primary production and respiration in a shallow aquatic system occurs both on the bottom as well as in the water column. Production can be partitioned by isolating samples of the planktonic portion in clear and opaque bottles suspended at the station and subtracting the plankton effect from an estimate of total metabolism.

<u>Open-water Net Community Production</u>

Oxygen change values were adjusted for diffusion except where they were taken in the lower stratum of stratified water. Diffusion was calculated from:

$$\text{Diffusion} = K \times \text{Percent Saturation Deficit}$$

where K is the diffusion coefficient, assumed to be 0.35 mg/l/hr per unit of Percent Saturation Deficit (after McKellar 1975) and

$$\text{Percent Saturation Deficit} = \text{Saturation Deficit} \,/\, \text{Average DO}$$

where

$$\text{Saturation Deficit} = \text{Saturation DO} - \text{Average DO}.$$

Average DO is the average of dissolved oxygen values (in mg/l) measured during a specified measurement period and Saturation DO is the saturation level of dissolved oxygen (mg/l) at the temperature and salinity of the sample as computed from the equation of Truesdale et al. (1955). Alternative formulas that give similar saturation values are given in Standard Methods, 15th Edition. The differences in results using these various equations are small relative to the potential error in the estimate for the diffusion coefficient K (McKellar 1975).

Oxygen change values in mg/l/hr were converted to $mg/m^2/hr$ by multiplying by the volume of water in liters over a square meter of bottom (depth in meters x 1000 l per meter of depth over a square meter of bottom).

## Light/dark Bottle Method for Plankton Gross Primary Production

At each station, approximately 10 l of water were collected by inserting a plastic bucket completely below the surface to avoid aeration of the sample. Water was gently siphoned from the bucket into duplicate clear and opaque 300 ml BOD bottles fitted with clips. About 500 ml of water was allowed to overflow from the bottles before they were capped to prevent aeration of the samples. The light and dark bottles were suspended in mid-water by clipping to a floating bar anchored to the bottom. After several hours, the bottles were retrieved and the oxygen measured using an air-calibrated YSI Model 57 oxygen meter fitted with a stirring BOD electrode. The difference between the final readings in the clear bottles and those in the opaque bottles (divided by the time of incubation) was used as an estimate of gross primary production by the plankton community.

## Dome Method for Community Respiration

Opaque plastic domes were made from the top halves of 200 l opaque pickle barrels, which had wide-mouth screw tops. Each dome covered approximately 0.25 $m^2$ (actual surface area varied slightly among domes) and enclosed 50 to 130 l of water (depending on the dome and on how far the dome was inserted into soft sediment). Tops were modified to allow oxygen measurement, water sample withdrawal, and water circulation within the dome (see following paragraph). With the tops removed, two numbered domes were dispatched from the boat at each station and gently pressed into undisturbed sediment (far enough to create a good seal) before any other sampling activities began. The tops were then screwed into place to begin an incubation period lasting from two to six hours. Oxygen was monitored periodically (every 2-3 hr) with the same calibrated meters used for open-water measurements. Water samples were removed initially and at the end of the incubation period to detect changes in ammonium. Water temperature and salinity were also measured in the domes. After the incubation, the distance that the domes penetrated the sediment was determined so the volume of water incubated could be determined (in order to compute oxygen change per square meter of bottom). Before the domes were removed, any submerged vegetation in the domes was collected for dry weight analysis as described previously.

Water in domes must circulate to homogenize dissolved oxygen and to provide the minimum circulation required by oxygen electrodes, without disrupting bottom sediments (which expose anaerobic surfaces that chemically remove oxygen from the water and thereby confound the estimate of biological metabolism). Therefore, a 12 v submersible water pump (Attwood Mini-King 360) was attached to the inside of each lid and connected to a rheostat for controlling impeller speed. A y-connector attached to the pump outlet directed flow first across holes through which twin oxygen electrodes were inserted. A water diffusion cylinder (a plastic bottle riddled with holes) was attached at right angles to each end of the y-connector in order to reduce the force of the outflow after it had passed the oxygen electrode and therefore prevent (as much as possible) disruption of the often very soft bottom sediments. A long piece of tubing sufficient to reach from the inside of the dome to the boat was installed through the top for sampling small quantities of dome water at the beginning and at the end of the incubation period. At the end of the incubation, duplicate water samples were withdrawn for BOD as a check on the effect of any disruption of bottom sediments. This was especially important in very soft sediments. If BOD was higher than the BOD taken from the open water at the station, then the increase was assumed to be the effect of increased chemical oxygen demand caused by disrupted sediments.

## Statistical Analysis

The statistical analyses performed on these data are essentially exploratory, as opposed to analyses done to confirm a hypothesis. They help to highlight possible relationships among environmental variables and stimulate hypothesis development. Data for each station and date were encoded into a microcomputer for analysis with the SAS statistical analysis program. Each station was encoded with a "location" code (1 for the outermost station in each system to 4 for the upstream-most station) and a "system" code (1W for the western set of stations, 2C for the central set, and 3E for the eastern set). Each sampling trip was numbered and encoded with the month and year of the trip and a "daycode," the time in days since the first sampling trip. These codes allowed analysis of effects across locations, systems, and dates.

Bar graphs were produced with Lotus-123. Means and standard deviations for each station were computed over all sampling trips in which measurements were taken and graphed by location within system. Means and standard deviations for each sampling trip were also computed over all stations and graphed by date of sampling trip. Reported bar graphs are accompanied by results of appropriate statistical analyses.

Two analysis-of-variance (ANOVA) models were performed on all data (see Appendix A). First, the effects on each measured parameter of the location and system of measurement were analyzed along with any interaction effect of location and system. Second, the effect of date of measurement and the location x date interaction were analyzed. The Waller-Duncan test was used to separate significantly different groups of means by location, system, and date. In the bar graphs of this report, groups separated by the Waller-Duncan test are denoted by letters over the bars that represent each station or date mean. Within a graph, bars with the same letter are not significantly different.

In a second set of analyses, the means and standard deviations of measured parameters at each of the 12 stations were calculated and analyzed by regression analysis (Appendix B). Regressions were performed separately for each station mean and station standard deviation against location. Additional regression analyses were performed on these means and standard deviations to explore possible relationships between environmental variables and benthic animals and plants.

To explore effects of temporal variation in environmental parameters on temporal changes in benthic animals and plants, a series of correlation analyses were done separately by location (Appendix C). Analysis by location



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highlights temporal correlations among variables that differ at different locations.

# RESULTS

## Environmental Variables

### Salinity

Sampling stations were chosen along a salinity gradient within each of the three tributary-nearshore bay systems. The results of this selection are shown in Figure 2. The effect of location was highly significant. From upstream to outer stations, mean surface salinity (over the 12 field trips of the pilot and final studies combined) steadily declines from 32.8 ppt to 19.7 ppt in the western system (Taylor River-Little Madeira Bay); 29.6 ppt to 10.2 ppt in the central system (Snook Creek-Joe Bay-Trout Cove); and 25.4 ppt to 11.3 ppt in the eastern system (Highway Creek-Long Sound-Little Blackwater Sound). The effect of system was also significant. Mean surface salinity over all stations and trips within a system decreases from west to east (26.2, 21.1, and 17.6, respectively).

During the 10 to 12 field trips to each station, surface salinity was highly variable, especially at the upstream stations in each of the three systems. From west to east, the salinity minima and maxima measured at the upstream-most stations were: 3.7 to 46.6 ppt at Taylor River Pond 3 (TRPD3), 0.5 to 25.5 at Snook Creek Pond 3 (SCPD3), and 0.1 to 32.5 at Highway Creek Pond 2 (NWHP2). This is an average range of 33.4 ppt at the upstream stations. The outermost stations of the western and eastern systems were the least variable. At the mouth of Little Madeira Bay (LMBHS) to the west,



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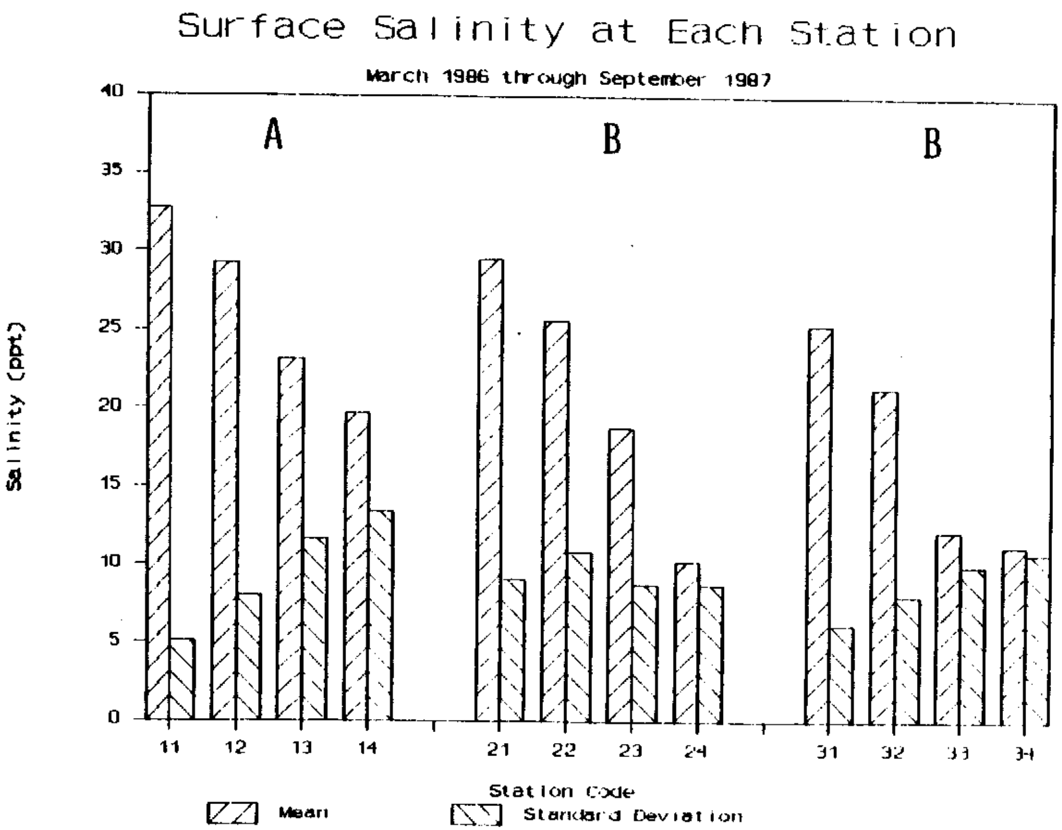


**ANALYSIS OF VARIANCE RESULTS**

**SURFACE SALINITY**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .0001 |
| System | .0002 |
| Loc X Syst | .8508 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | A |
| 3 | B |
| 4 | C |

Figure 2



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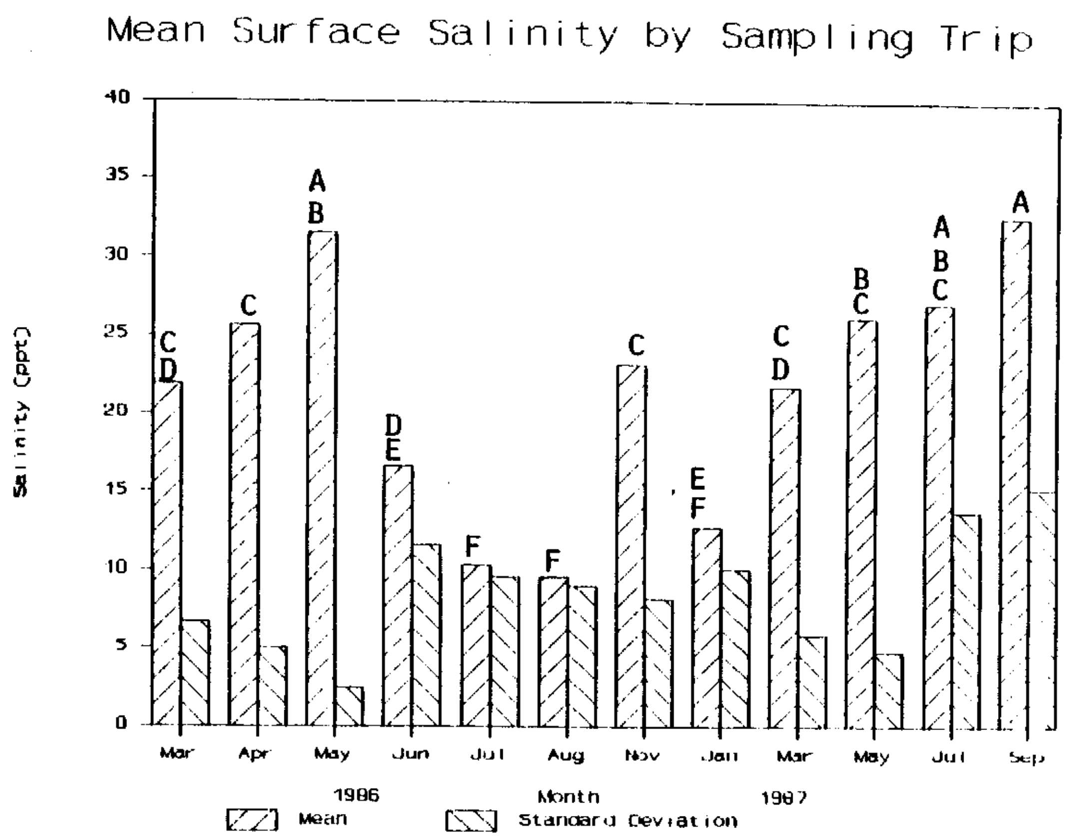
salinity ranged from 28.0 to 46.5 ppt. Salinity at the northeast corner of Little Blackwater Sound (NELBS) ranged from 15.5 to 34.7 ppt. The outermost of the central stations (Northeast Trout Cove, NETCV) ranged from 8.2 to 46.0 ppt. The 8.2 value occurred during the wettest sampling trip (August 1986), and is unlike any of the other values measured at that station, or at any of the other outermost stations. Without that unusual value, the range is from 21.8 to 46.0 ppt. This adjustment yields an average range of 20.6 ppt for the outermost stations. Thus, not only is average salinity lower at upstream stations, but temporal variation in salinity tends to be higher there too. Significant regressions were obtained with location both for the mean and the standard deviation of surface salinity at each station (see Appendix B, Observations 4 and 15).

Seasonal variation was high in general. As shown in Figure 3, mean surface salinity (over all stations) rose during the first few of the 12 field trips from an intermediate level in March 1986 (21.9 ppt) to a sub-maximum in May 1986 (31.47 ppt), after which it dropped to its lowest level in August 1986 (9.6 ppt). By November, however, surface salinity was again much higher (23.1 ppt), but dropped to a sub-minimum by January 1987 (12.7 ppt). During 1987, salinity continually rose to its highest level in September 1987 (32.56 ppt). Not all stations reached their maximum in this final trip, however. The two most upstream stations of the central and eastern systems were highest in May 1986, as was the second to the outermost station of the eastern system (Northeast Long Sound, NELSD). In fact, during September 1987, the upstream-most stations in the central and eastern systems (Snook Creek Pond 3 and Highway Creek Pond 2) had surface salinities considerably below their respective means. Spatial variation in surface




**ANALYSIS OF VARIANCE RESULTS**

**SURFACE SALINITY**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .0001 |

Figure 3



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salinity during September 1987 was the highest found among the 12 field trips. Other months of high spatial variation in surface salinity were June 1986 and July 1987.

Despite the shallowness of the stations, water was often salinity stratified, as indicated in Table 2. Stratification was generally greatest at the smaller upstream ponds (Taylor River Pond 3, and Snook Creek Pond 3), which were protected from wind-induced mixing and received freshwater run-off. The greatest stratification recorded was a difference of 18.6 ppt between the surface and bottom salinities in Snook Creek Pond 3 in September 1987. Stratification was most frequent, however, in bays near the mouths of creeks, except at the station in Little Madeira Bay near the mouth of Taylor River (LMBTR). This station was shallow, open to the wind, and received less discharge than that of other similarly positioned stations. The most frequently stratified station was the one near the mouth of Highway Creek in Northeast Long Sound. This station was stratified with a difference of 1 ppt or more on six out of 10 field trips. Stratification was infrequent and subtle at the outermost stations, and in the largest ponds, where wind-induced mixing was more effective. Near the mouth of Little Madeira Bay (LMBHS), the least stratified station, stratification greater than 1.0 ppt was detected on only one out of 12 field trips.

Of course, bottom salinity is the most relevant to benthic animals and plants. In general, the statements about surface salinity also apply to bottom salinity. As illustrated in Figure 4, mean bottom salinity significantly decreases from outer to upstream stations in each of the three systems (22.9 to 33.1 ppt, 13.2 to 30.4 ppt, and 11.4 to 26.9 ppt, from west to east, respectively). Means likewise significantly decline from west to

Table 2. Occurrence of salinity stratification at stations on morning reading (S indicates water was stratified, N indicates not stratified).

| | TRIP | | | | | | |
|---|---|---|---|---|---|---|---|
| STATION | Aug 86 | Nov 86 | Jan 87 | Mar 87 | May 87 | Aug 87 | Sep 87 |
| 11 (LMBHS) | N | N | N | N | N | N | N |
| 12 (LMBTR) | S* | N | S | N | N | N | N |
| 13 (TRPD1) | N | S | S | S | N | N | N |
| 14 (TRPD3) | S | N | N | S | N | N | N |
| 21 (NETCV) | S | N | N | N | S | N | S |
| 22 (LTLJB) | S | N | N | N | N | N | S |
| 23 (NEJBY) | N | N | S | N | N | N | S |
| 24 (SCPD3) | N | S* | S | N | N | N | S |
| 31 (NELBS) | N | N | N | N | N | N | S* |
| 32 (NELSD) | S | N | S | N | N | S | S |
| 33 (HCPD1) | N | S | N | N | N | N | S |
| 34 (NWHP2) | N | S | N | N | N | S* | S |

* mixing occurred by afternoon, destroying the stratification



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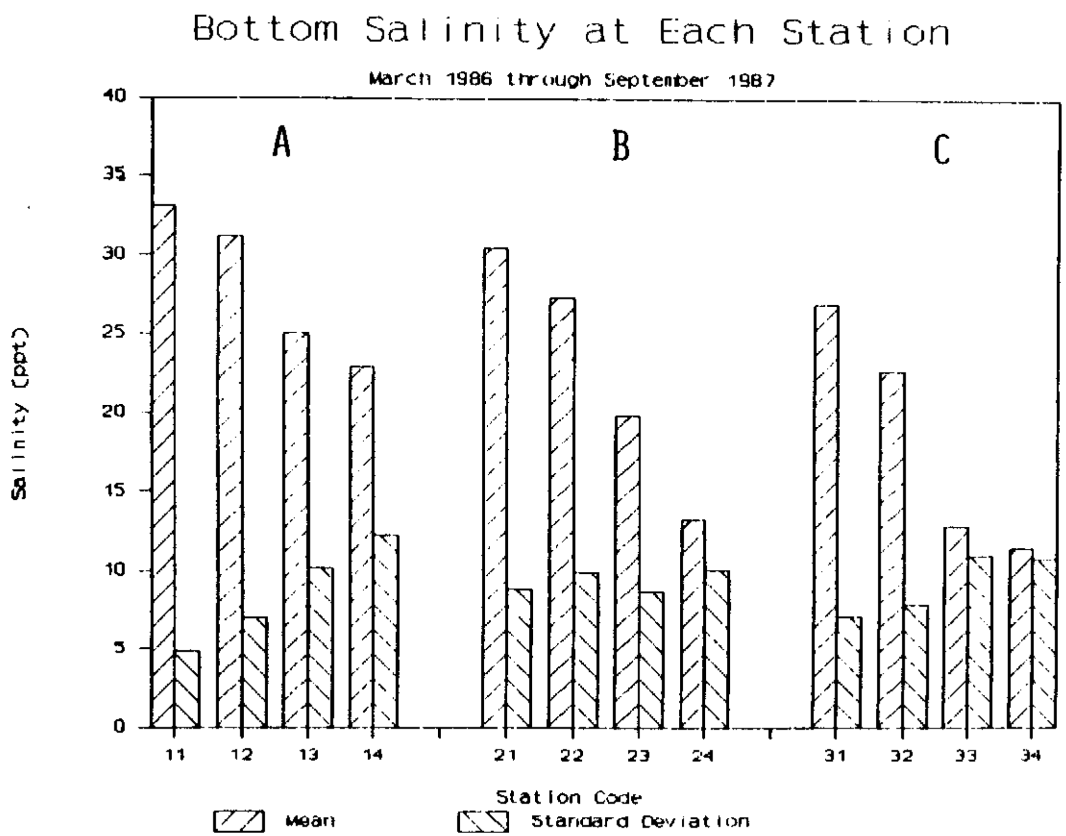


**ANALYSIS OF VARIANCE RESULTS**

**BOTTOM SALINITY**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .0001 |
| System | .0001 |
| Loc X Syst | .8458 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | A |
| 3 | B |
| 4 | B |

Figure 4

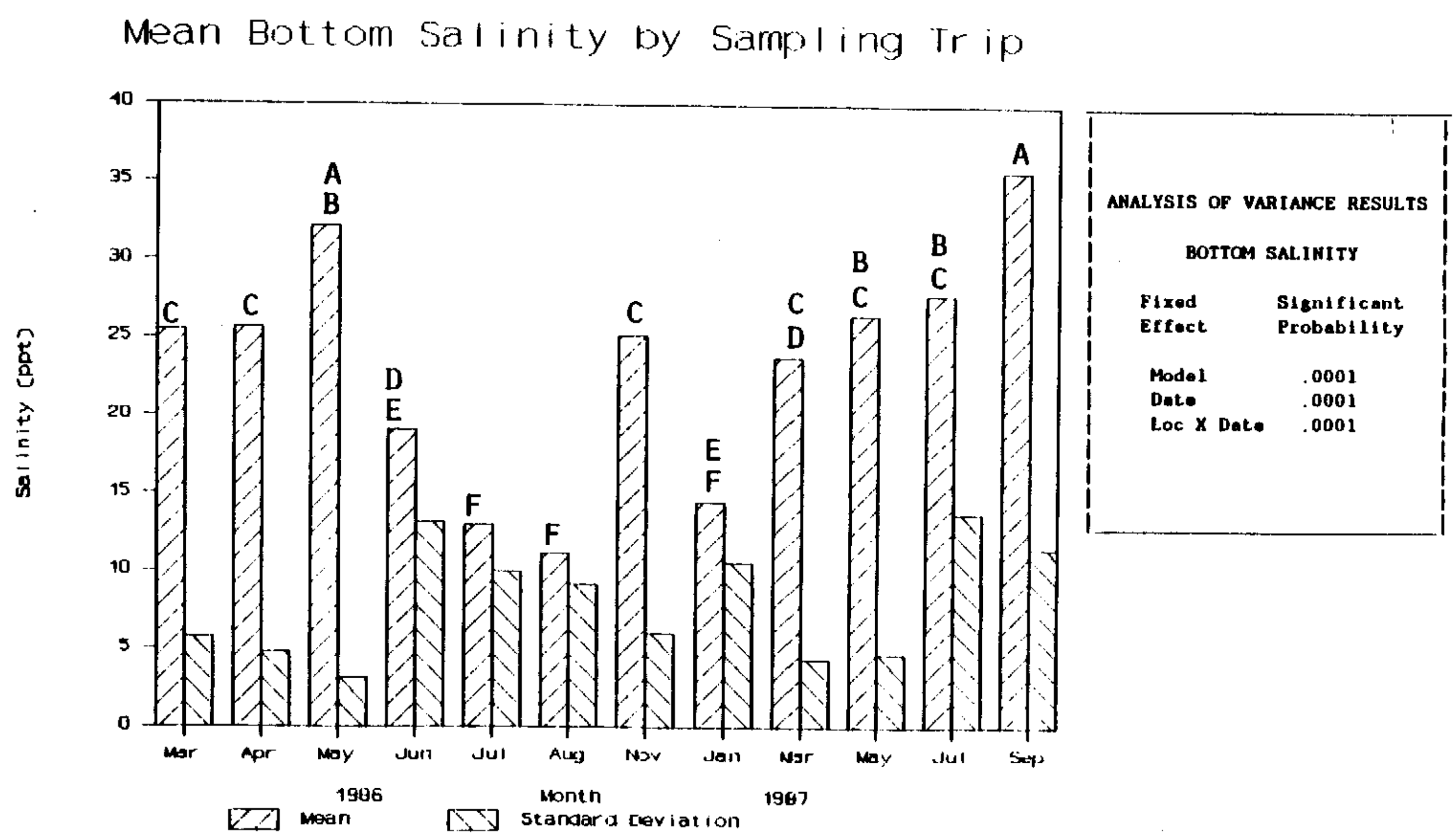
Mean Bottom Salinity by Sampling Trip
Salinity (ppt)
40
35
30
25
20
15
10
5
0
C
C
A
B
D
E
F
F
C
E
F
C
D
B
C
B
C
A
Mar
Apr
May
Jun
Jul
Aug
Nov
Jan
Mar
May
Jul
Sep
1986
Month
1987
Mean
Standard Deviation
ANALYSIS OF VARIANCE RESULTS
BOTTOM SALINITY
Fixed Effect
Significant Probability
Model .0001
Date .0001
Loc X Date .0001

Figure 5



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east. Temporal variation in bottom salinity (Figure 5) is slightly lower than surface variation in the western and central systems, but is slightly higher in the eastern system. Like surface salinity, mean bottom salinity in upstream stations is significantly more temporally variable than in downstream stations, even without adjusting the Northeast Trout Cove station for the low value in August 1986 (see Appendix B, Observations 7 and 8). Seasonal variation in mean salinity (over all stations) followed the same pattern as surface salinity, with the exception that spatial variation in September 1987 was not quite as high. Bottom salinities at the upstream stations in September were maximal or well above average, despite the much fresher water above at some stations.

Because of the presence of water masses of varying density, and the opposing energies of wind from the south and freshwater from the north, surface and bottom salinity frequently varied at a station during the day. Over all stations and trips, salinity change between the morning measurement and 4 to 6 hours later averaged about 1.1 ppt. Daily changes of more than 2.0 ppt occurred in 20% of the pool of all measurements, and changes of more than 4.0 ppt occurred in 5% of the pool. The greatest recorded salinity change in one day was a decrease of 6.9 ppt at Northeast Long Sound in May 1987. Daily changes of greater than 2 ppt were most frequent and intense at this station, which is situated near the mouth of Highway Creek. The next to the outermost station of the central system (Little Joe Bayou; LTLJB) was of similar frequency of daily change. The station least susceptible to daily salinity changes was the outermost station of the western system (the mouth of Little Madeira Bay; LMBHS).

## Run Currents

Currents in the three tributaries were highly variable from trip to trip. Data from the outer runs of the various tributaries are given in Table 3. In the western system (Taylor River) and in Trout Creek of the central system, flow direction was inland (flood) in 45% of the measurements. In Snook Creek (upper central system) and Highway Creek (eastern system), however, flow direction was outward (ebb) in 90% of the measurements. Although individual measurements of flow in Trout Creek -- the largest run monitored -- were usually the highest, the frequent alternation of flow direction caused the mean flow to be negative and the standard deviation to be much higher than in any of the other measured runs.

Mean flows in the inland-reaching tributaries (Taylor River, Snook Creek, and Highway Creek), were congruent with the pattern found for mean salinity. Mean salinity was inversely correlated with mean flow. The Highway Creek system not only had the highest positive mean flows, but also exhibited the most consistent flows of the three tributaries (and the lowest mean salinities). Taylor River, with the highest mean salinities, had low and highly variable mean flows.

Although currents were usually measurable in the stream runs, currents at the benthic stations within the ponds were usually below the limits of detection.

## Water Temperature

Unlike salinity, water temperature did not vary greatly from upstream to outer stations (Figure 6), however, a statistically significant regression with location was obtained (Appendix B, Observation 20). Seasonal variation



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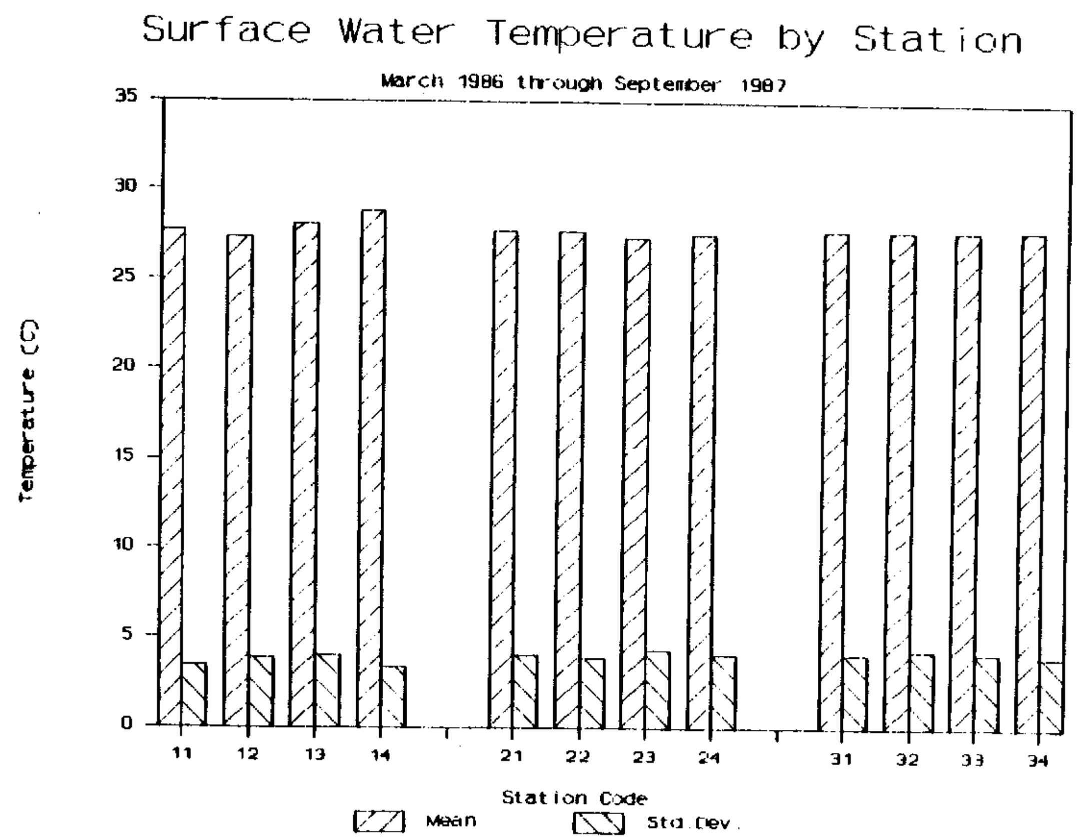
Table 3. Current and discharge from stream runs in Northeast Florida Bay (negative values indicate upstream flow direction).

| Run | CURRENT (cm/s) Min | Max | Avg | S.D. | Width (m) | Depth (cm) | Discharge ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| Western System: | | | | | | | |
| TRRN1 | -15.6 | 31.4 | 5.7 | 15.7 | 6.4 | 176 | 0.49 |
| TRRN2W | -11.9 | 6.4 | 0.6 | 6.8 | 7.6 | 175 | 0.06 |
| TRRN3 | -5.7 | 4.2 | -0.5 | 3.2 | 8.8 | 164 | -0.05 |
| Central System: | | | | | | | |
| TCRN1 | -50.6 | 32.7 | -12.9 | 29.8 | 28.0 | 169 | -4.57 |
| JBYRN | -16.4 | 26.0 | 3.2 | 15.8 | 11.0 | 122 | 0.31 |
| SCRN1 | -4.7 | 28.0 | 13.0 | 11.8 | 9.0 | 133 | 1.13 |
| SCRN2 | 0.0 | 11.0 | 3.7 | 4.2 | 7.0 | 143 | 0.27 |
| Eastern System: | | | | | | | |
| HCRN1 | 4.6 | 26.6 | 13.3 | 6.5 | 7.3 | 174 | 1.28 |
| HCRN2 | 3.1 | 28.0 | 16.0 | 8.8 | 10.8 | 184 | 2.41 |




**ANALYSIS OF VARIANCE RESULTS**

**SURFACE WATER TEMPERATURE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .9999 |
| Location | .9731 |
| System | .8896 |
| Loc X Syst | .9958 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 6

in water temperature was much greater than spatial variation (Figure 7). Seasonal fluctuation also did not vary systematically from upstream to outer stations. Mean surface water temperatures (over all stations) ranged from 19.3 °C in January 1987 to close to 31.5 °C in both July 1986 and July 1987. Means for stations (over all field trips), however, only ranged from 26.8 °C at Snook Creek Pond 3 (SCPD3) to 28.2 °C at Taylor River Pond 3 (TRPD3). Daily temperature fluctuations at a station were comparable to differences found among station means. Mean daily temperature fluctuations of 5 to 6 °C occurred in summer and 2 to 3 °C in winter. The average daily increase between early and late measurements was 2.5 °C for surface water and 2.1 °C for bottom water.

Bottom temperatures generally behaved similarly to surface temperatures (Figures 8 and 9), though in salinity stratified water, bottom temperatures were frequently from 0.5 °C to as much as 18 °C warmer than surface water. Bottom temperatures warmer by 0.5 °C or more occurred in 44% of the measurements, whereas bottom temperatures cooler than surface temperatures by the same amount occurred in only 3 of 84 measurements (12 stations and 7 trips between August 1986 and September 1987). Bottom temperatures more than 10 °C warmer than surface temperatures occurred four times: twice at Snook Creek Pond 3 (SCPD3), once at Taylor River Pond 3 (TRPD3), and once at Little Madeira Bay near the mouth of Taylor River (LMBTR).

Water pH

Like water temperature, pH did not vary systematically from station to station (Figure 10). Values ranged between 7 and 9 with a mean of 8.1. No low pH values attributable to swamp water draining from the mainland were

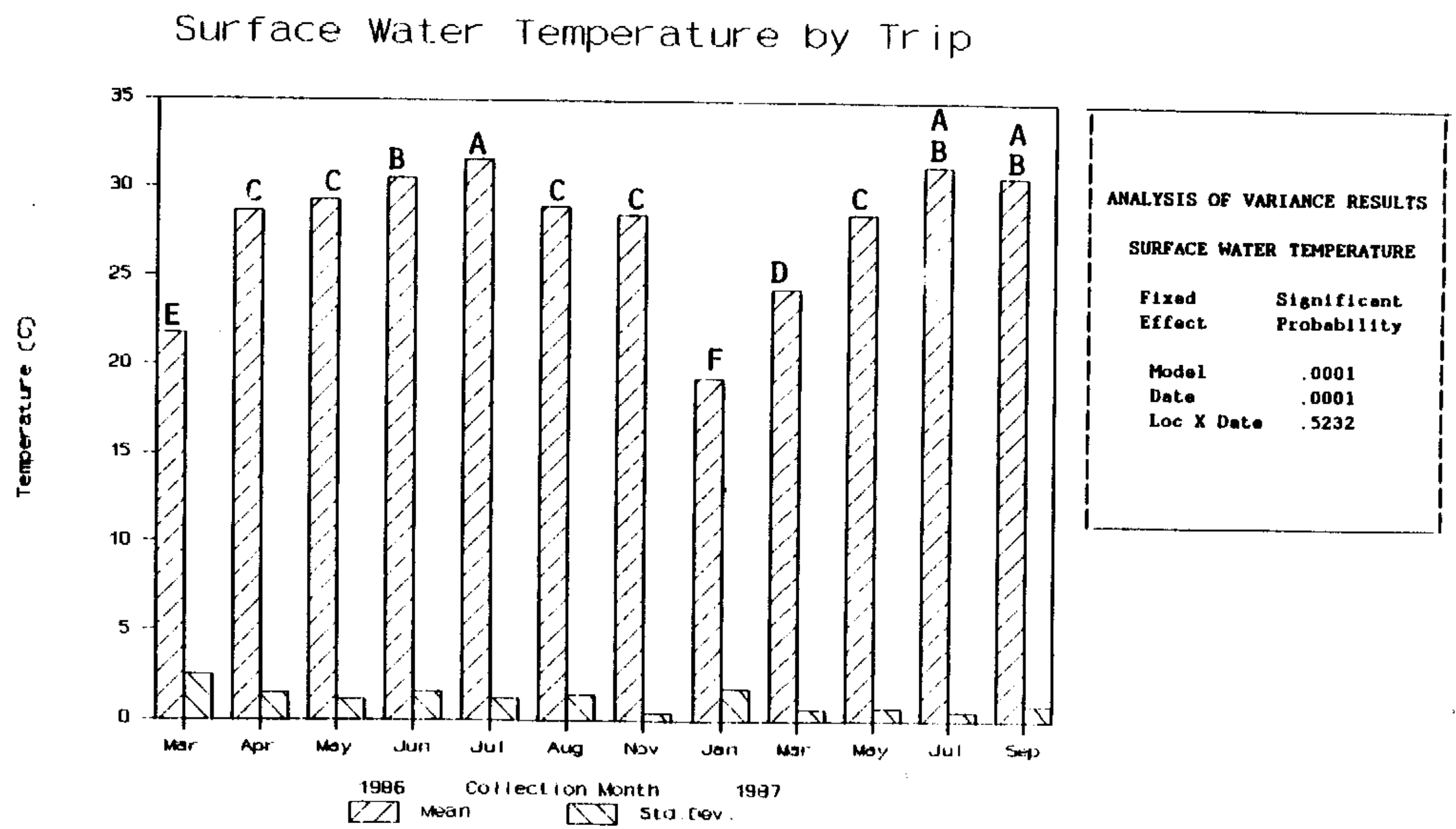
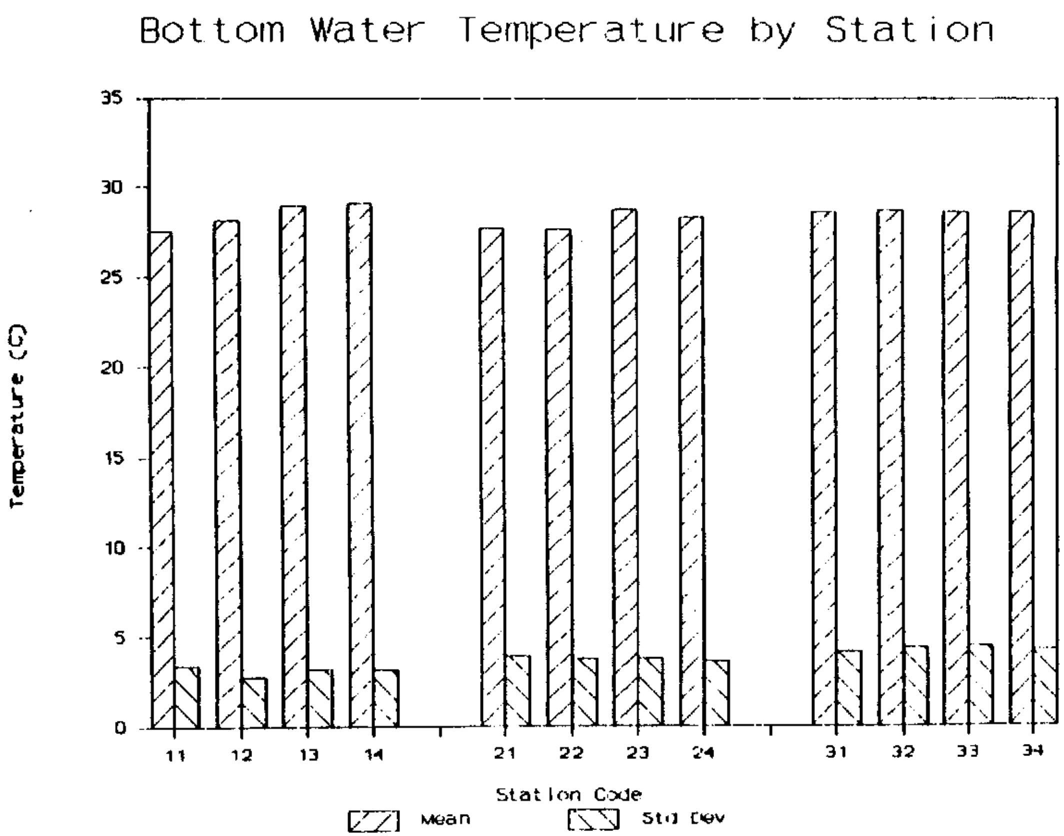

Surface Water Temperature by Trip
Temperature (C)
35
30
25
20
15
10
5
0
E
C
C
B
A
C
C
F
D
C
A B
A B
Mar
Apr
May
Jun
Jul
Aug
Nov
Jan
Mar
May
Jul
Sep
1986
Collection Month
1987
Mean
Std. Dev.
ANALYSIS OF VARIANCE RESULTS
SURFACE WATER TEMPERATURE
Fixed Effect
Significant Probability
Model .0001
Date .0001
Loc X Date .5232

Figure 7




**ANALYSIS OF VARIANCE RESULTS**

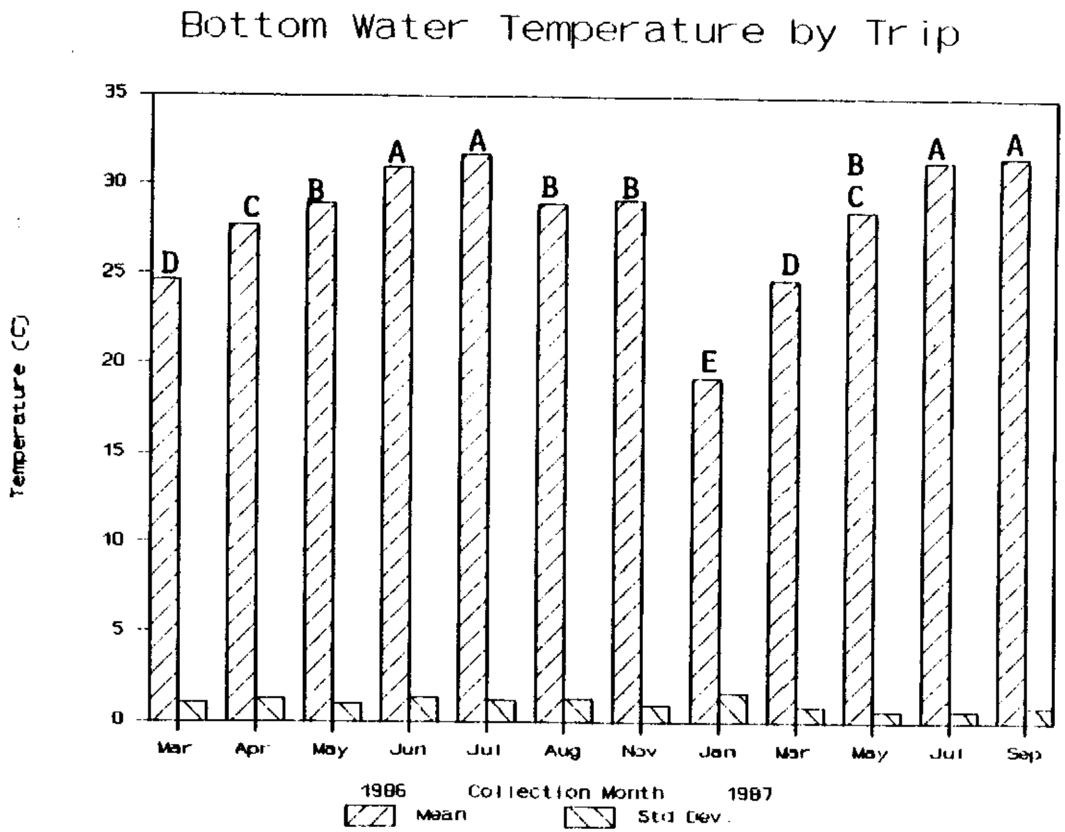
**BOTTOM WATER TEMPERATURE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .9982 |
| Location | .8157 |
| System | .8411 |
| Loc X Syst | .9933 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 8




**ANALYSIS OF VARIANCE RESULTS**

**BOTTOM WATER TEMPERATURE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .7537 |

Figure 9



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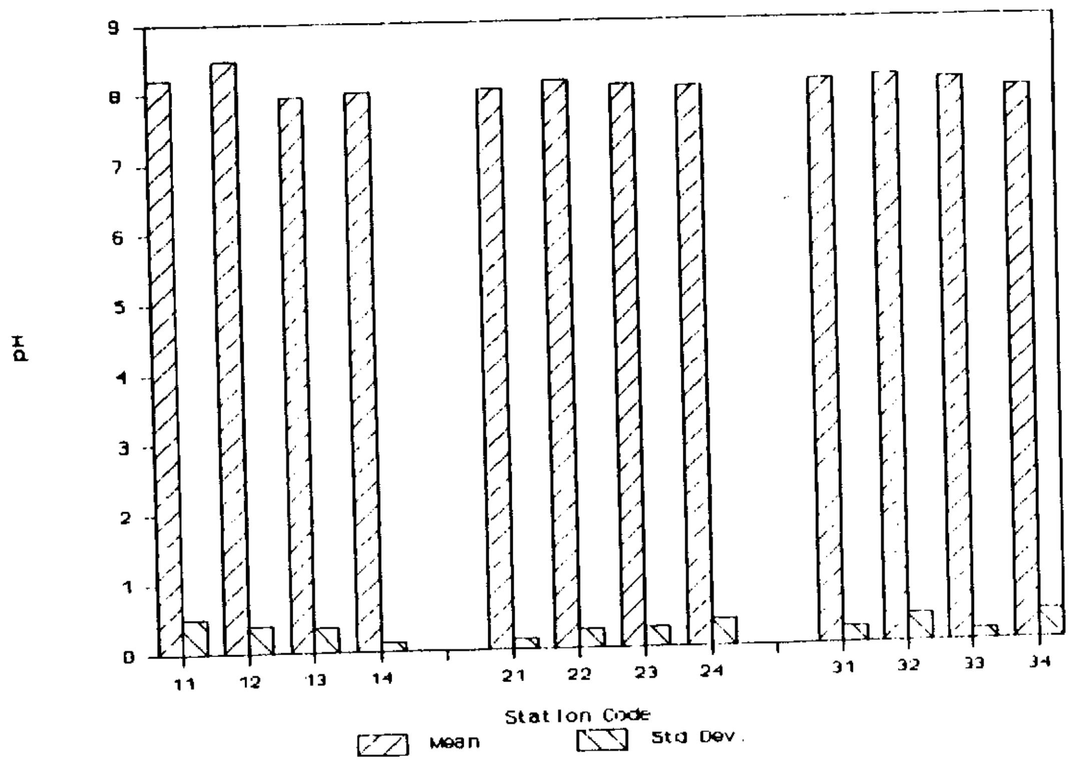
Surface Water pH by Station




**ANALYSIS OF VARIANCE RESULTS**

**SURFACE WATER pH**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .3153 |
| Location | .1009 |
| System | .4962 |
| Loc X Syst | .5341 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 10

found, though water in Taylor River and Snook Creek was often darkly stained. Even in stratified water, pH of surface water was not very different from that of bottom water. A mean difference of 0.07 pH units occurred in 23 surface vs bottom measurements, which included all sampling stations. The maximum difference between surface and bottom was 0.30 pH units. No detectable difference was found in 52% of these comparisons. Station means (over all sampling trips), ranged from 7.85 at Taylor River Pond 1 to 8.75 at the mouth of Little Madeira Bay. Seasonal mean pH (over all stations) varied from 7.78 in January 1987 to 9.04 in July 1987 (Figure 11).

## Water Depth and Sediment Characteristics

Stations were selected to be as similar in water and sediment depths as possible to reduce confounding of salinity gradient effects. Mean water depths (over all trips) ranged from 66 cm in Little Joe Bayou (LTLJB) to 101 cm in Northeast Little Blackwater Sound (NELBS). Mean depths at stations did not vary systematically from upstream to outer stations (Figure 12). The grand overall mean water depth was 81 cm. Mean water depths (over all stations) varied seasonally from lows around 74 cm in late spring and early summer and highs near 90 cm in late summer, through fall and early winter (Figure 13).

Water levels are influenced more by the direction and speed of the wind than by lunar tides in northeast Florida Bay, especially east of Little Madeira Bay. The absolute value of the differences between two depth readings taken 4 to 6 hours apart gives a relative index of daily changes in water level. Changes ranged from 0 to 23 cm among stations and sampling



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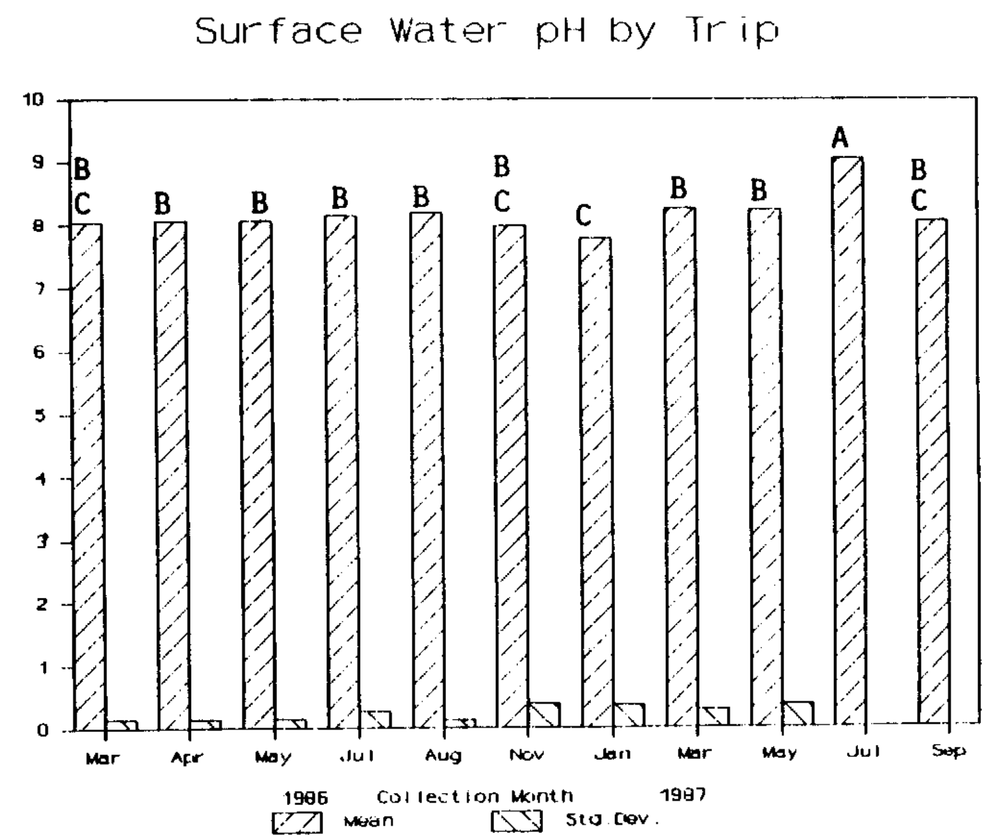
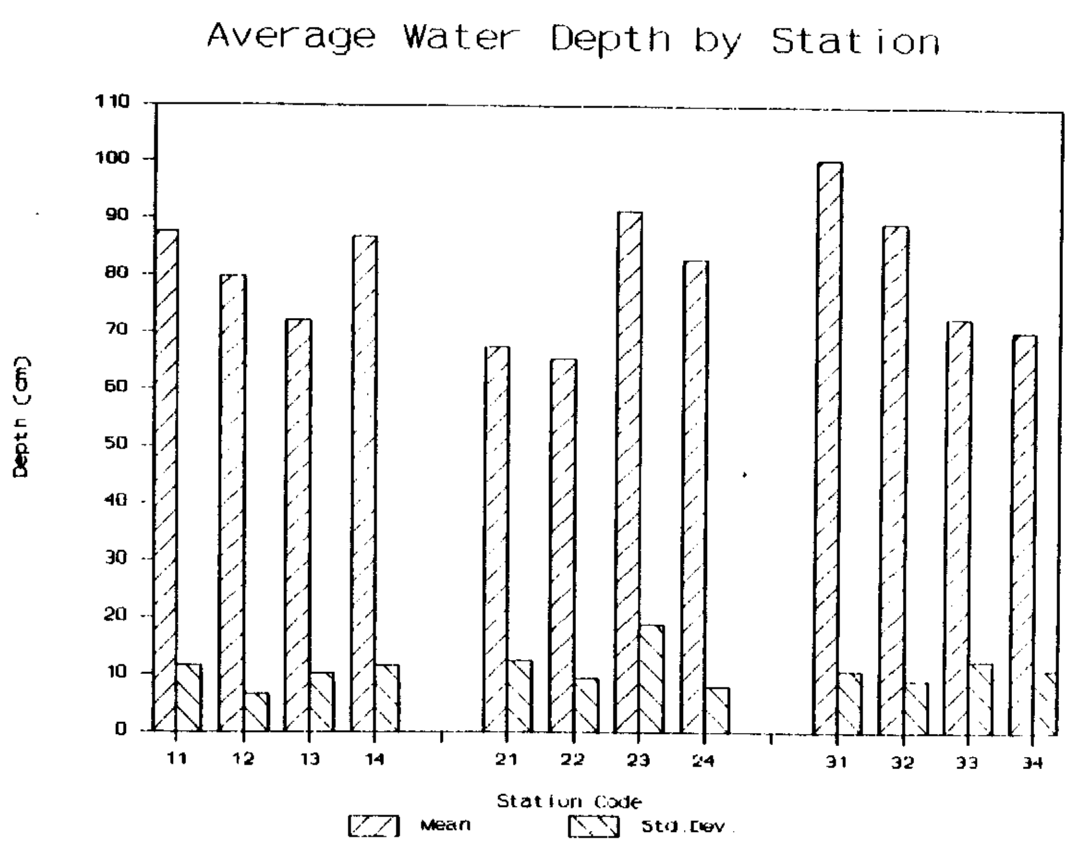



**ANALYSIS OF VARIANCE RESULTS**

**SURFACE WATER pH**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0003 |
| Date | .0001 |
| Loc X Date | .1613 |

Figure 11




**ANALYSIS OF VARIANCE RESULTS**

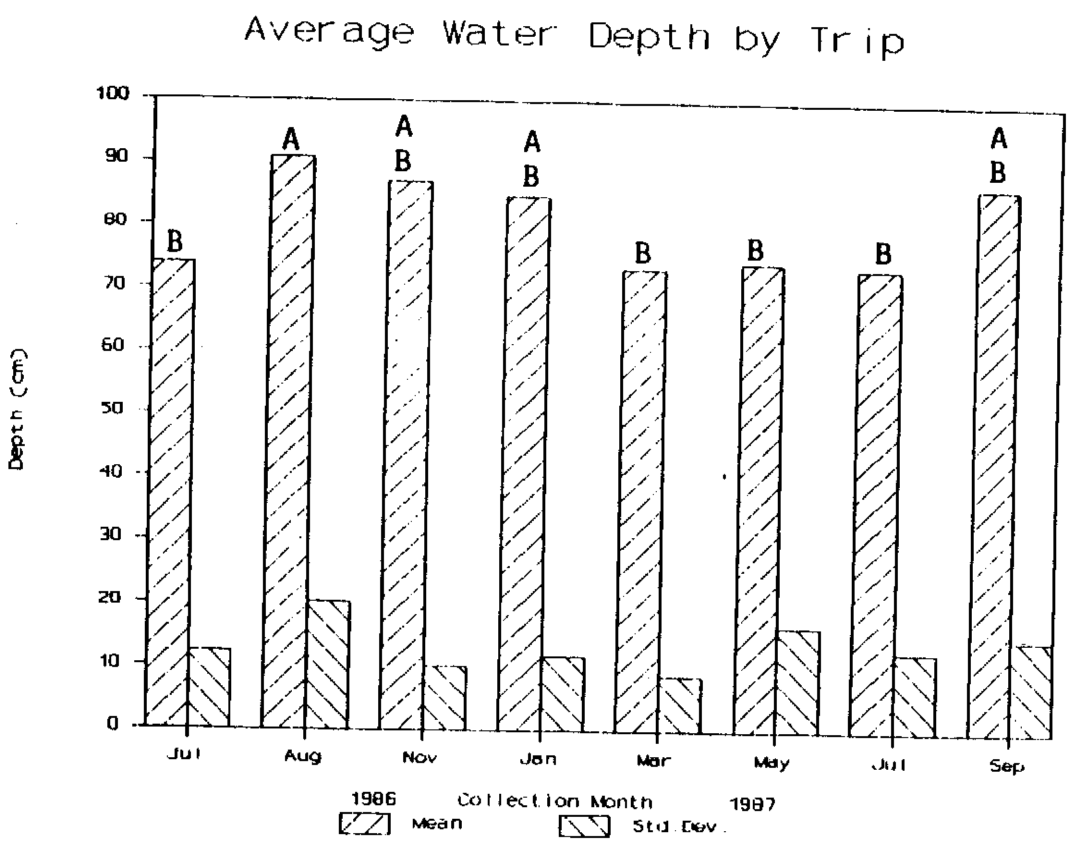
**AVERAGE WATER DEPTH**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .1770 |
| System | .0935 |
| Loc X Syst | .0001 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 12




**ANALYSIS OF VARIANCE RESULTS**

**AVERAGE WATER DEPTH**

| Fixed Effect | Significant Probability |
| --- | --- |
| Model | .3062 |
| Date | .0119 |
| Loc X Date | .8682 |

Figure 13

dates, with an overall average change of 3.3 cm. The greatest mean daily change at a single station (6.9 cm) occurred near the mouth of Little Madeira Bay (LMBHS), where lunar tides are greatest among the stations (Figure 14). The western system stations exhibited greater daily water level changes than those of the central or eastern systems, where regular lunar tidal ranges are generally too small to be detectable with stick gauges.

<u>Sediments</u>. Sediment thickness among stations ranged from 40 cm at Taylor River Pond 3 (TRPD3) to 110 cm at the mouth of Little Madeira Bay (LMBHS), with an overall mean of 80 cm. No consistent pattern of spatial variation in thickness occurred among the stations, as suggested by the highly significant interaction between system and location (Figure 15). Sediments in the outermost stations, however, seemed to have higher bulk density than those upstream, as judged by moisture content (Figure 16), resistance to human body weight, and ease of resuspension during sampling activities. Sediments can be characterized as fine carbonate marl (lime mud) with an organic content of about 9% (Figure 17). Mean organic content of sediment ranged from 4.9% at Northeast Trout Cove (NETCV) to 17.2% at Northeast Joe Bay (NEJBY), but no significant effect of location was detected.

The inorganic portion of sediments at the sampling stations averaged 96% acid soluble (calcium carbonate) and ranged from 91% at Little Joe Bay (LTLJB) to 99.9% at the mouth of Little Madeira Bay (LMBHS). Systematic variation in calcium carbonate content from upstream to downstream was not apparent in any of the systems (Figure 18). Western system sediments, however, seem slightly higher in carbonate content than those of the other two systems ranging from 98.1 to 99.9% acid soluble. The weight distribution



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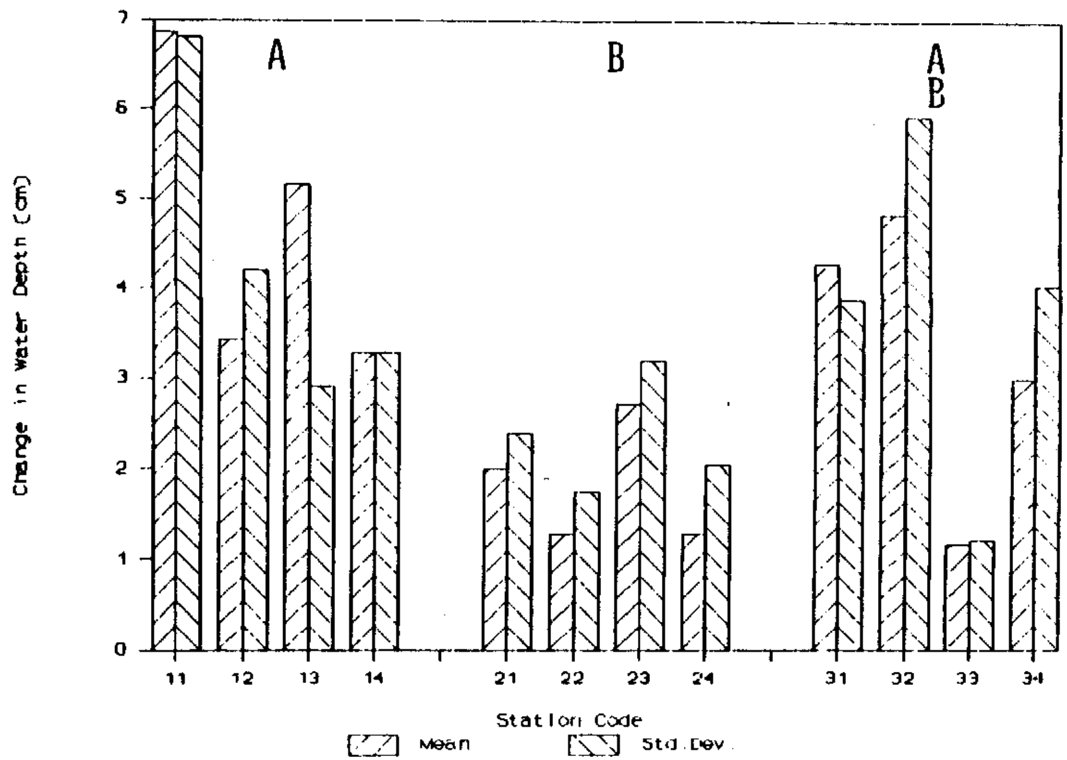
Daily Change in Water Depth by Station




**ANALYSIS OF VARIANCE RESULTS**

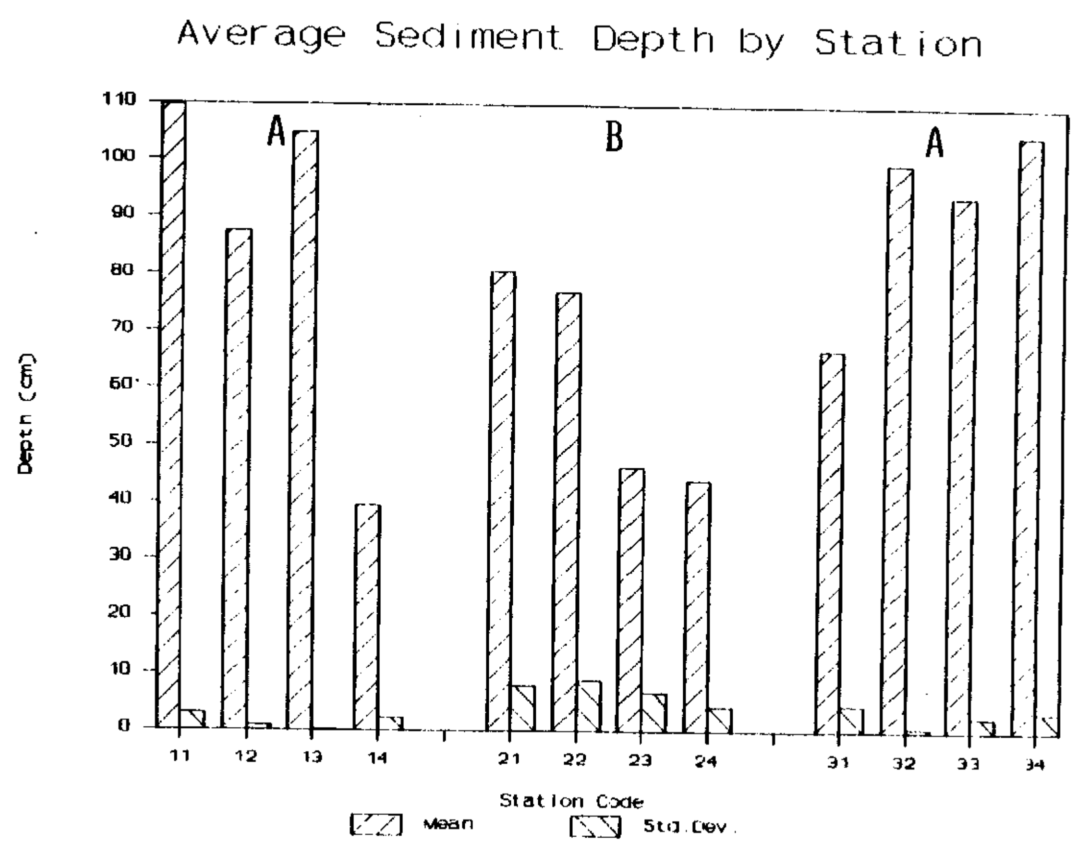
**DAILY CHANGE IN WATER DEPTH**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .2888 |
| Location | .5127 |
| System | .0447 |
| Loc X Syst | .5950 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 14




**ANALYSIS OF VARIANCE RESULTS**

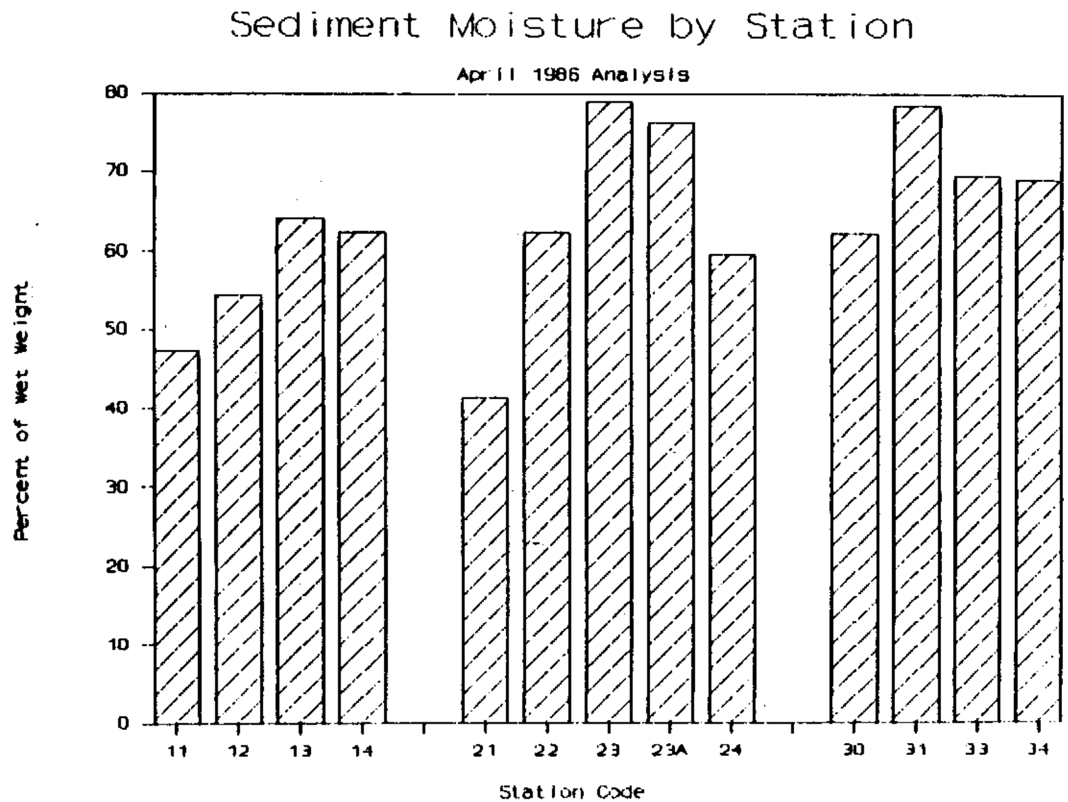
**AVERAGE SEDIMENT DEPTH**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .0001 |
| System | .0001 |
| Loc X Syst | .0001 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | A |
| 3 | A |
| 4 | B |

Figure 15




**ANALYSIS OF VARIANCE RESULTS**

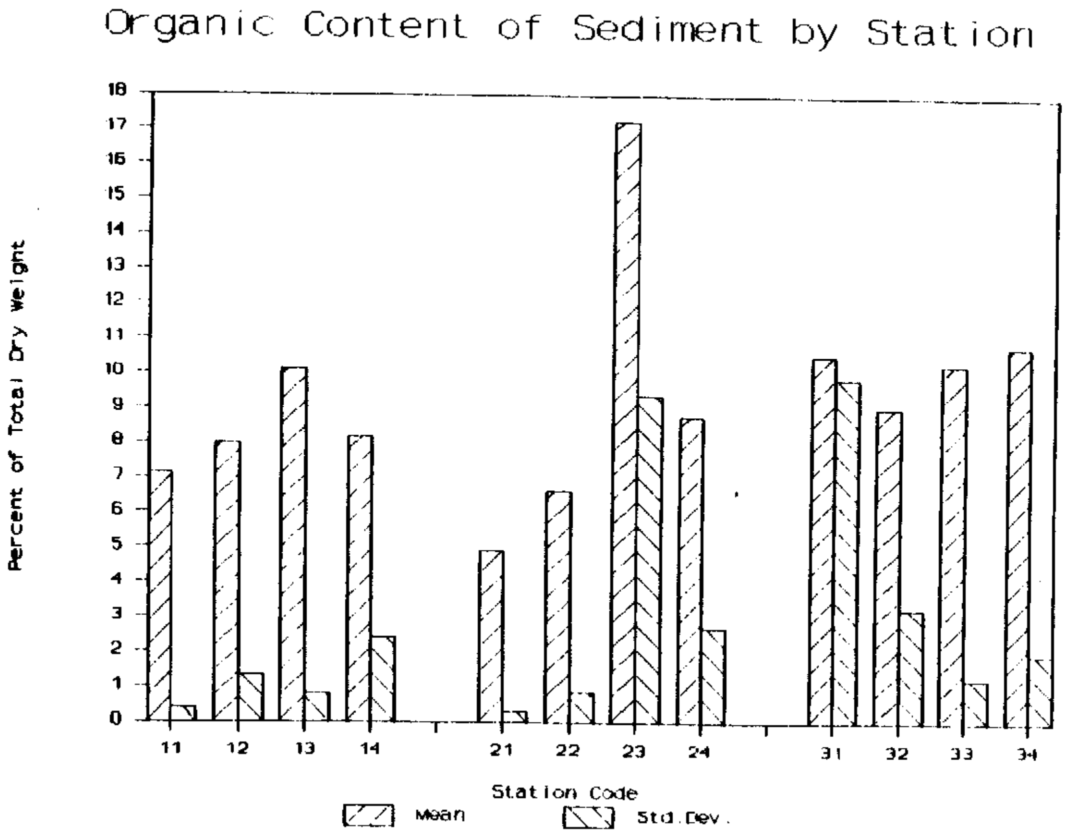
**SEDIMENT MOISTURE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .4789 |
| Location | .4789 |
| System | - |
| Loc X Syst | - |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 16




**ANALYSIS OF VARIANCE RESULTS**

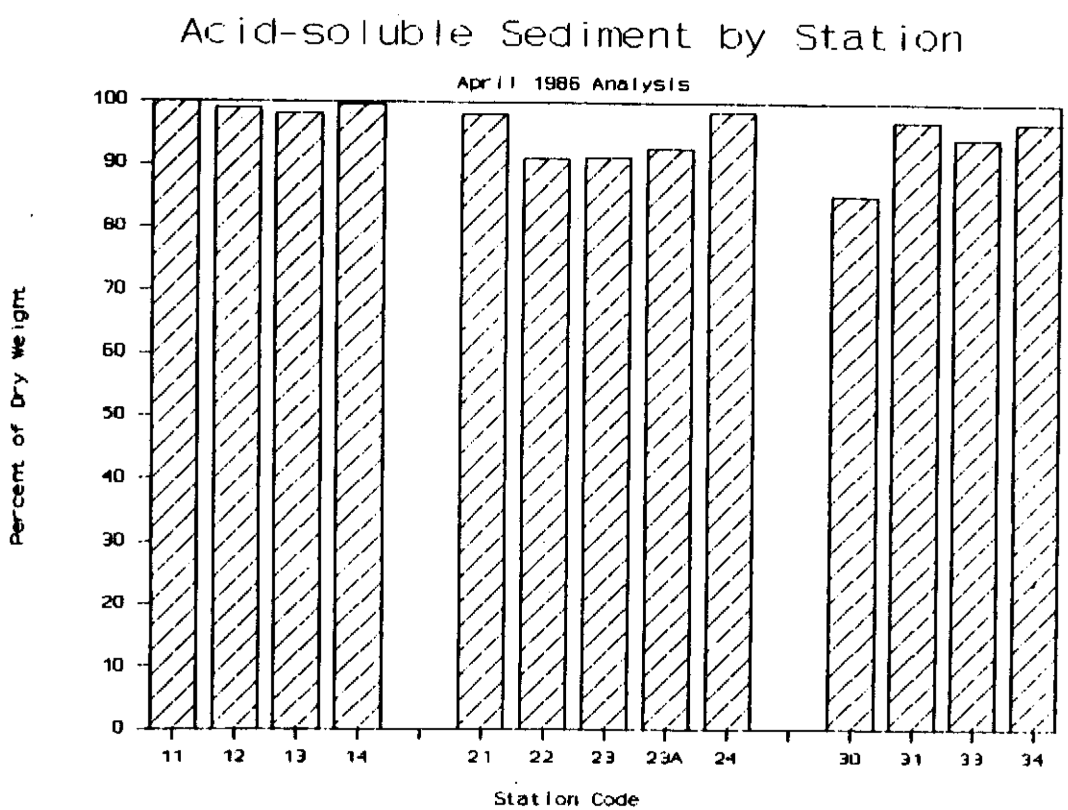
**ORGANIC CONTENT OF SEDIMENT**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .6553 |
| Location | .3216 |
| System | .7986 |
| Loc X Syst | .6229 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 17




**ANALYSIS OF VARIANCE RESULTS**

**ACID-SOLUBLE SEDIMENT**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .3486 |
| Location | .3486 |
| System | - |
| Loc X Syst | - |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 18

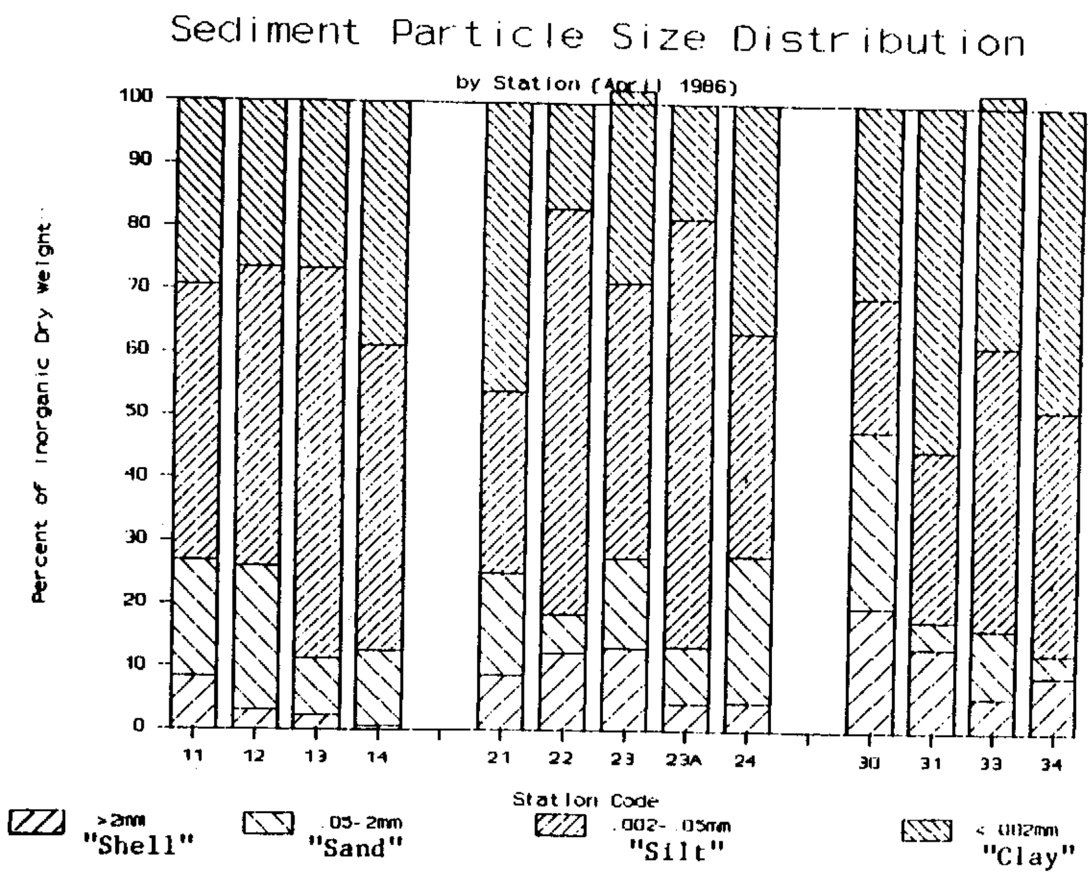
of inorganic particle sizes averaged 34% clay (< 0.002 mm), 44% silt (0.002 to 0.05 mm), 14% sand (0.05 to 2.0 mm), and 8% larger particles (mostly shells and shell fragments). Particle size distribution did not vary systematically from upstream to downstream (Figure 19).

Weather

Wind Speed and Direction. As shown in Figure 20, average wind speed (over all stations) ranged from 1.7 m/s (3.7 mph) in September 1987 to 3.8 m/s (8.6 mph) in August 1986 with an overall average of 2.7 m/s (6.0 mph). Wind speed did not systematically vary from upstream to outer stations (Figure 21). Average wind speed (over all trips) varied by only 0.9 m/s (2.0 mph), from 2.3 m/s (5.2 mph) at the well-protected Taylor River Pond 1 to 3.4 m/s (7.2 mph) at the stations in ponds 1 and 2 of Highway Creek, which are somewhat open to the south and east, and are surrounded by much shorter (stunted) mangrove trees. The average direction from which the wind blew during sampling trips between August 1986 and September 1987 was between ESE and SE. More northerly winds (but still primarily from the east) blew during the November 1986 and May 1987 field trips. West winds were rare, but made sampling difficult at stations that were not protected by land to the west and south (LMBHS, LMBTR, NETCV, NEJBY, NELBS, and NELSD). West winds occurred at one or more of these stations in August 1986, January 1987, and September 1987. The January and September 1987 west winds were less than 3 m/s, but those of August 1986 were from 2.5 to 7 m/s. The trips with the most highly variable wind speeds and directions were those in January and March 1987. September 1987 was also variable in direction, but with very low average speeds.



203




**ANALYSIS OF VARIANCE RESULTS**

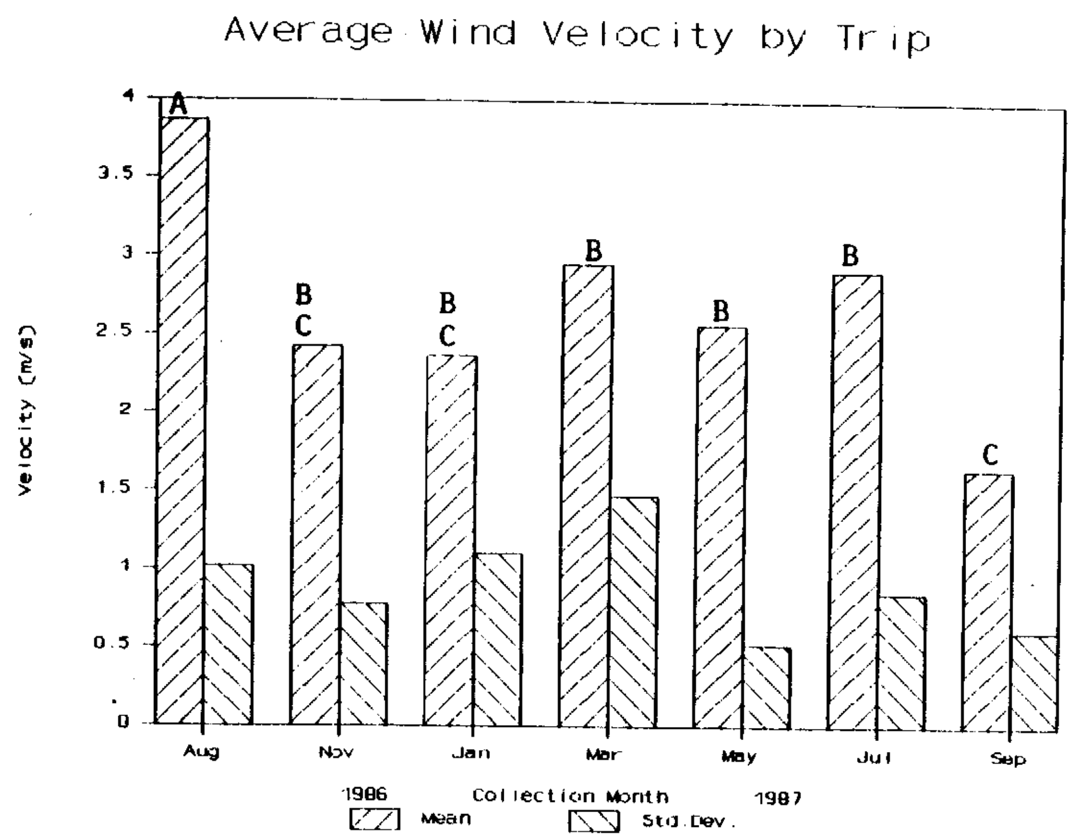
**EFFECT OF LOCATION ON SEDIMENT QUALITY**

| Independent Variable | Significant Probability |
|---|---|
| Shell | .5919 |
| Sand | .9771 |
| Silt | .1081 |
| Clay | .1008 |

**WALLER-DUNCAN GROUPING**

| Location | Silt | Clay |
|---|---|---|
| 1 | B | A |
| 2 | A | B |
| 3 | AB | AB |
| 4 | AB | AB |

Figure 19



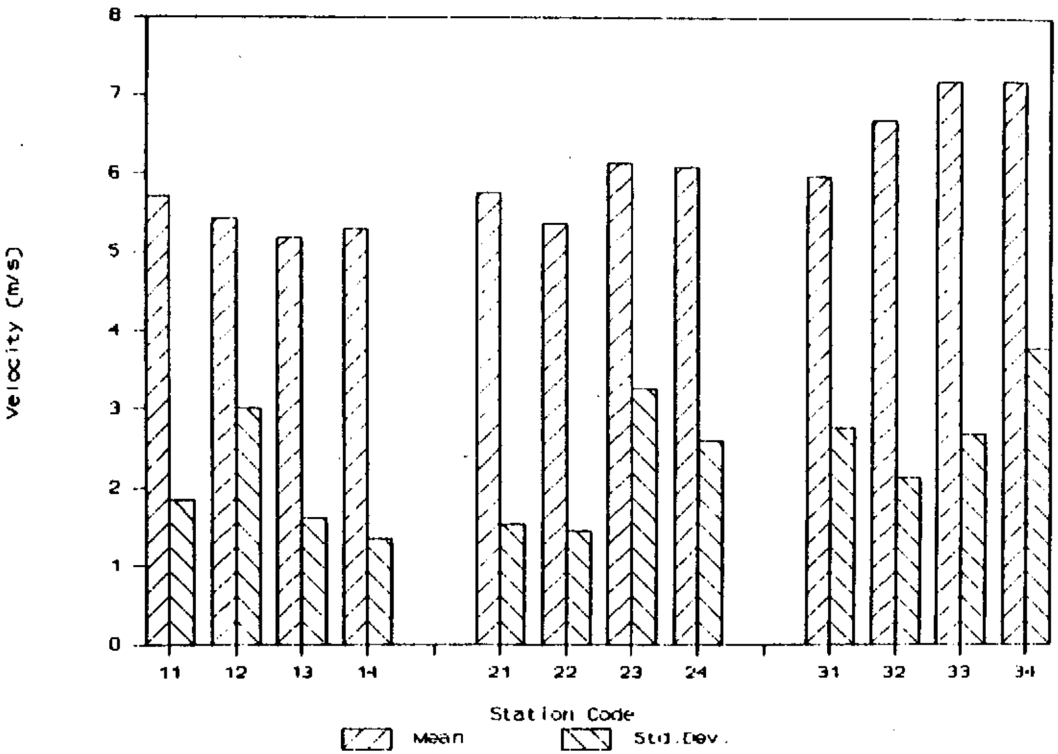

ANALYSIS OF VARIANCE RESULTS

AVERAGE WIND VELOCITY

| Fixed Effect | Significant Probability |
|---|---|
| Model | .1371 |
| Date | .0006 |
| Loc X Date | .8734 |

Figure 20

## Average Wind Velocity by Station




**ANALYSIS OF VARIANCE RESULTS**

**AVERAGE WIND VELOCITY**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .9155 |
| Location | .9326 |
| System | .1711 |
| Loc X Syst | .9798 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 21

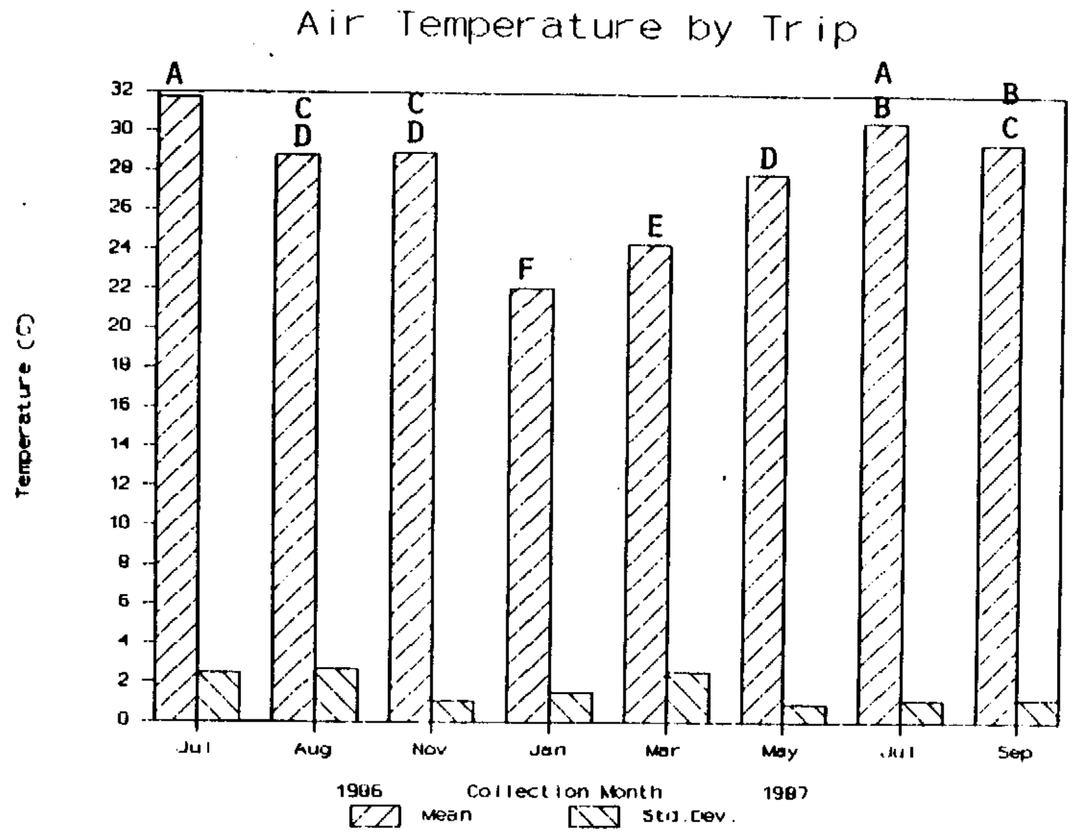
Air Temperature and Barometric Pressure. Mean air temperature over all stations (Figure 22) varied seasonally between August 1986 and September 1987 from a low of 22.1 °C in January 1987 to a high of 30.6 °C in July 1987. Air temperature was unseasonably low during the August 1986 trip (mean of 28.8 °C) due to considerable rain and cloud cover (see below). Mean barometric pressure during sampling trips ranged over only 4.7 mm (Hg) from a low of 754.6 mm in September 1987 to a high of 759.3 mm in August 1986. The overall average was 756.8 mm. Pressure usually remained nearly constant during sampling days, however, during August 1986, a drop of 9 mm was recorded during one sampling day.

Relative Humidity, Cloud Cover, and Occurrence of Rain. Average relative humidity during sampling trips (Figure 23) ranged from 69% in November 1986 and May 1987 to a high of 78% in August 1986, but these variations were not significantly different from trip to trip (see Figure 23 statistics). Overall mean relative humidity was 73%. Skies were generally clear to partly cloudy, except in August 1986 and March 1987, which were generally overcast. Rain occurred during more than half of the sampling in August 1986, and during about 20% of the sampling in March 1987. Rain occurred at only one additional station during the other trips (in September 1987), but was visible from two other stations in September. Rain was also visible from two stations in May 1987.

Light and Light Extinction. Midday light just beneath the surface of the water varied seasonally (Figure 24) from mean lows of 1005 and 1070 $\mu Ei/m^2/s$ during the overcast months of August 1986 and March 1987 to a high of 1875 $\mu Ei/m^2/s$ in November 1986. Individual measurements varied from 135 to 2400 $\mu Ei/m^2/s$ depending primarily on cloud cover during the measurement.



γ0

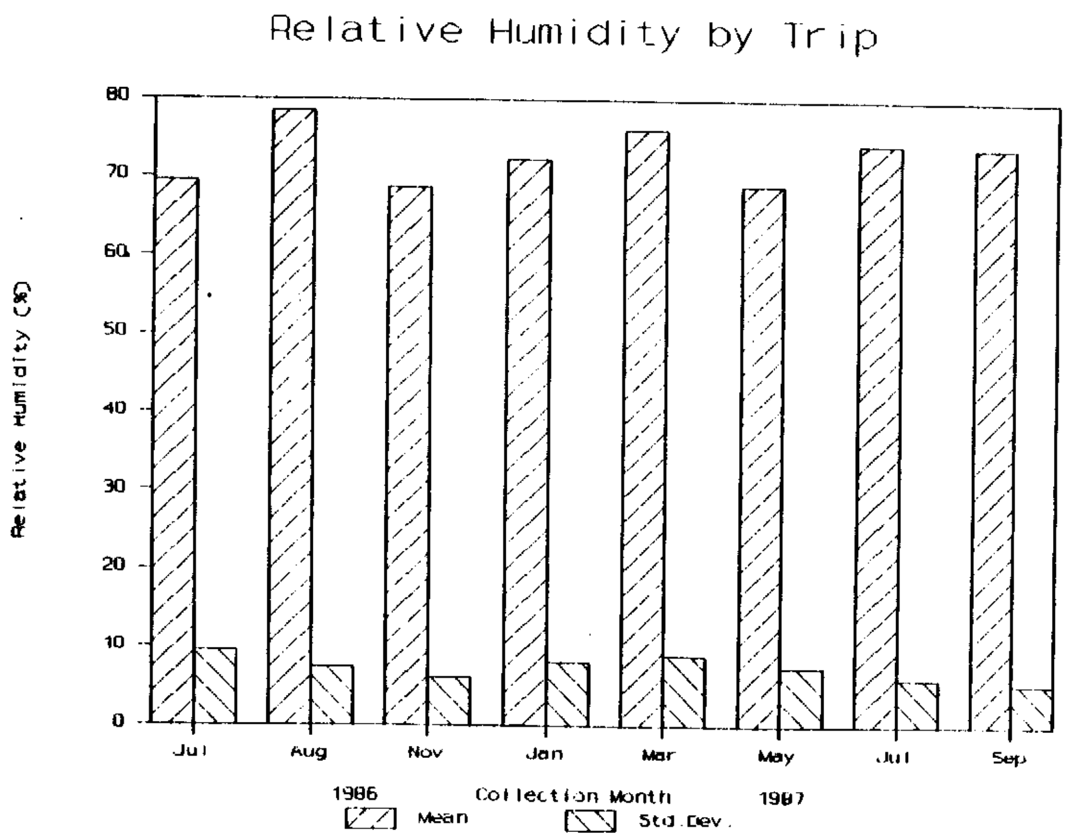



**ANALYSIS OF VARIANCE RESULTS**

**DAYTIME AIR TEMPERATURE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .7752 |

Figure 22

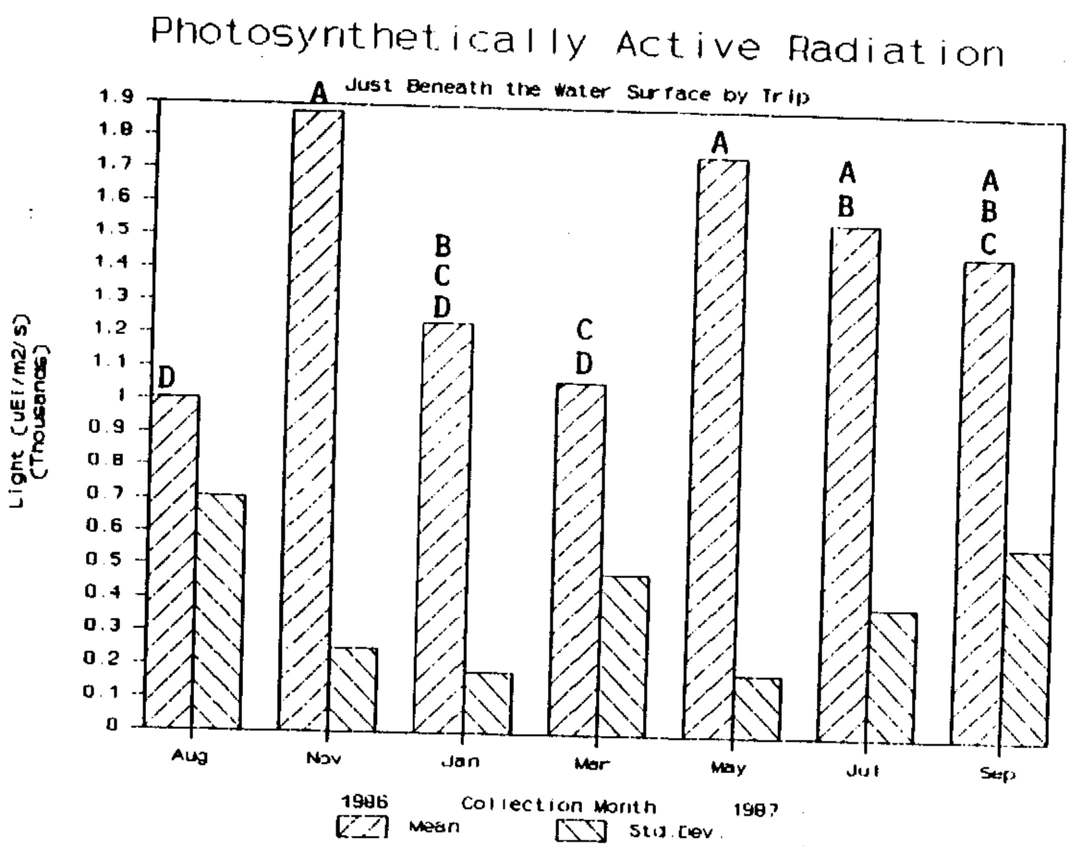



**ANALYSIS OF VARIANCE RESULTS**

**RELATIVE HUMIDITY**

| Fixed Effect | Significant Probability |
| --- | --- |
| Model | .7093 |
| Date | .1081 |
| Loc X Date | .9554 |

Figure 23




ANALYSIS OF VARIANCE RESULTS

PHOTOSYNTH. ACTIVE RADIATION

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0527 |
| Date | .0010 |
| Loc X Date | .6621 |

Figure 24

Midday light extinction coefficient (fraction of light reduction per m of depth, an exponential rate coefficient inversely related to water clarity) varied widely from 0.07 per m at Highway Creek Pond 1 (HCPD1) in November 1986 to 5.20 per m in Northeast Trout Cove (NETCV) during the same trip. Light extinction averaged 1.17 per m. Means did not vary significantly with station or with sampling trip (Figures 25 and 26). The outermost stations, however, seemed more variable with respect to light extinction. The least variable station was Little Joe Bayou (LTLJB), the second to the outermost station in the central system. With that exception, the most upstream stations in all systems were the least variable. A regression of the standard deviation of light extinction with location yielded an r-square of 31% and a significance level of > 90% (see Appendix B, Observation 22).

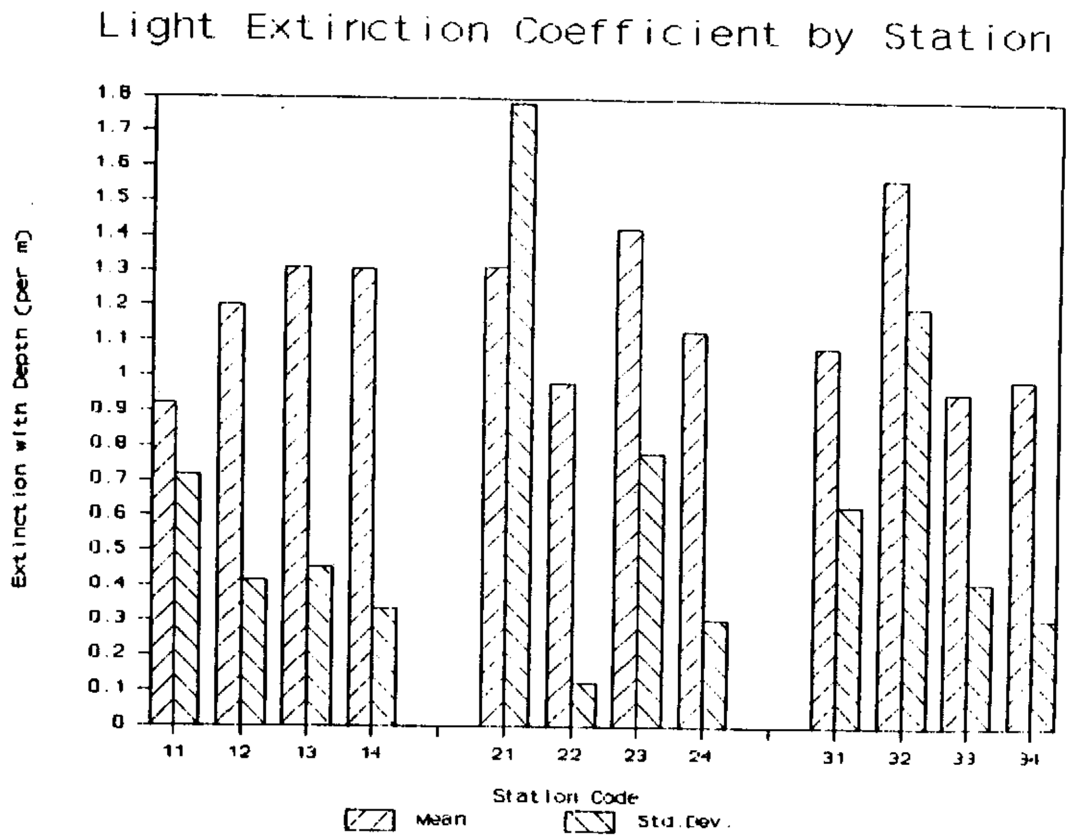
<u>Total Suspended Solids and Suspended Organic Matter</u>

Total suspended solids (TSS) in surface water averaged 11.8 mg/l. Station means (over all trips) ranged from 6.12 mg/l at Snook Creek Pond 3 (SCPD3) to 16.8 mg/l at Northeast Long Sound (NELSD). In each system, the lowest mean TSS in surface water occurred at the most upstream station (Figure 27). Although a significant effect of location was not detected with the ANOVA model reported in Figure 27, a significant regression of mean TSS with location was found, suggesting a trend of lower TSS upstream (Appendix B, Observation 16).

Mean surface TSS (over all stations) varied seasonally (Figure 28) from a low of 5.86 mg/l in November 1986 to a high of 26.3 mg/l in July 1987. TSS was nearly always higher in the lower layer of salinity-stratified water (in 30 out of 32 occurrences of stratified water). The average increase was 5.12



2 11




**ANALYSIS OF VARIANCE RESULTS**

**LIGHT EXTINCTION COEFFICIENT**

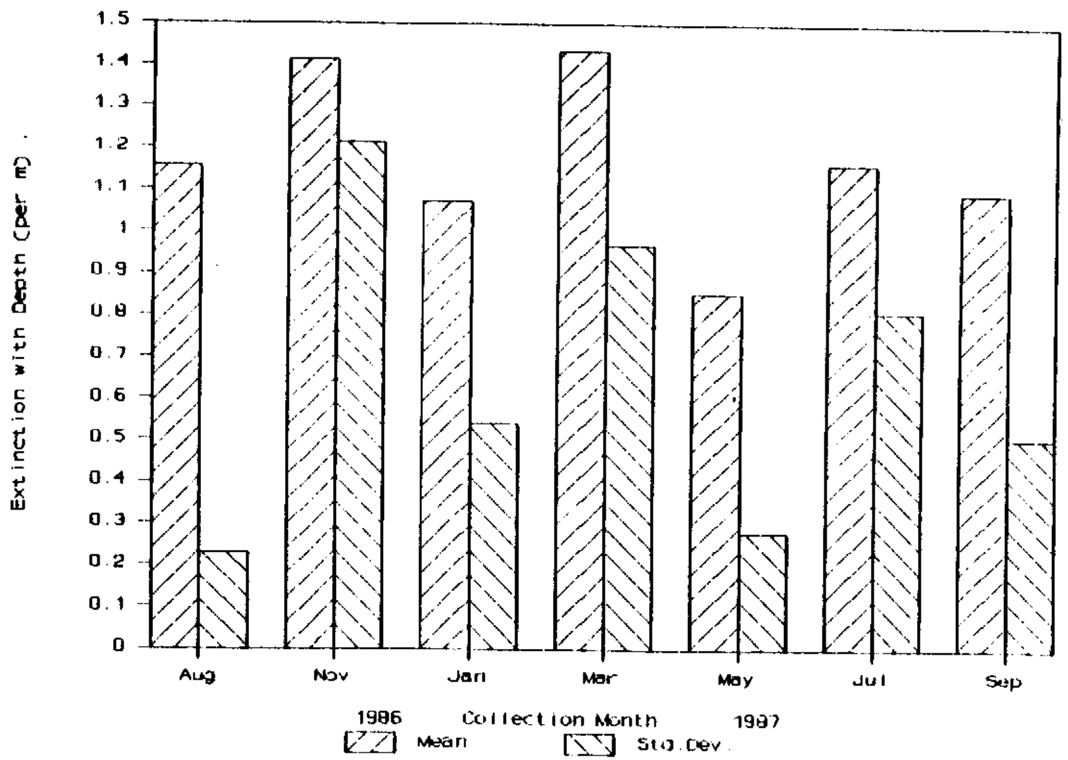
| Fixed Effect | Significant Probability |
|---|---|
| Model | .9380 |
| Location | .9373 |
| System | .9508 |
| Loc X Syst | .6503 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 25

## Light Extinction Coefficient by Trip

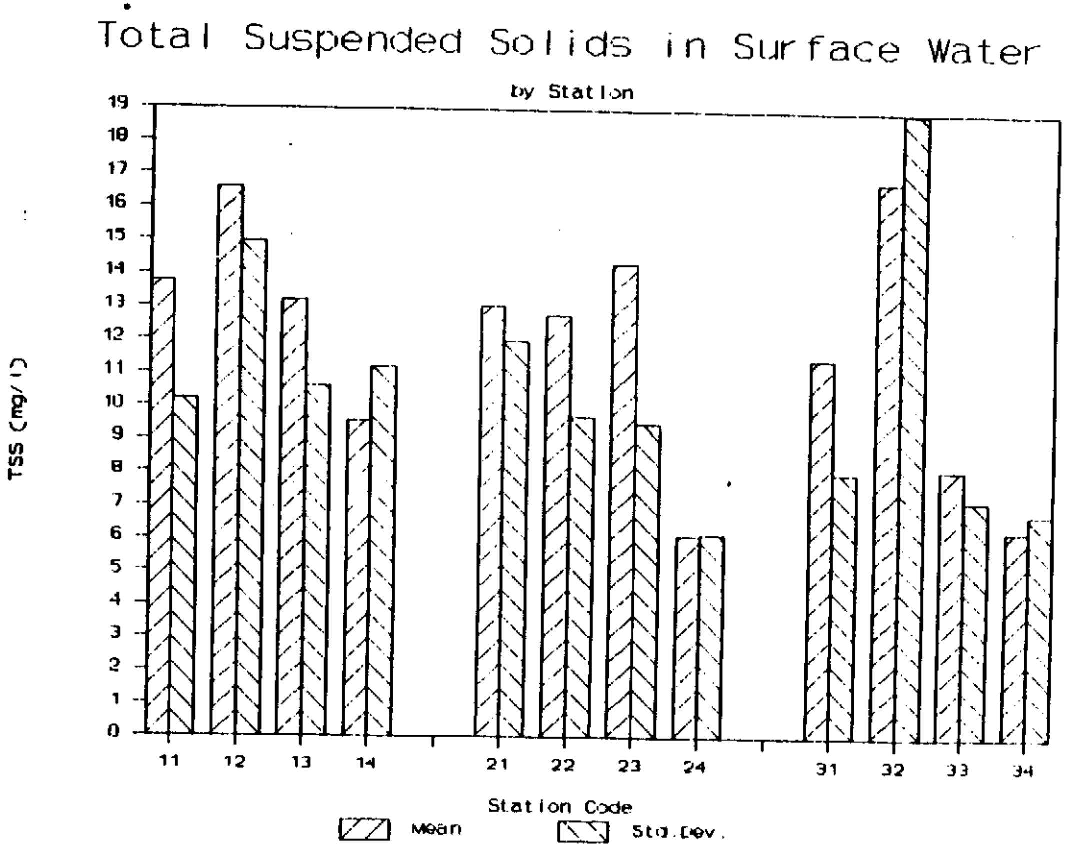



**ANALYSIS OF VARIANCE RESULTS**

**LIGHT EXTINCTION COEFFICIENT**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .4341 |
| Date | .5971 |
| Loc X Date | .3554 |

Figure 26




**ANALYSIS OF VARIANCE RESULTS**

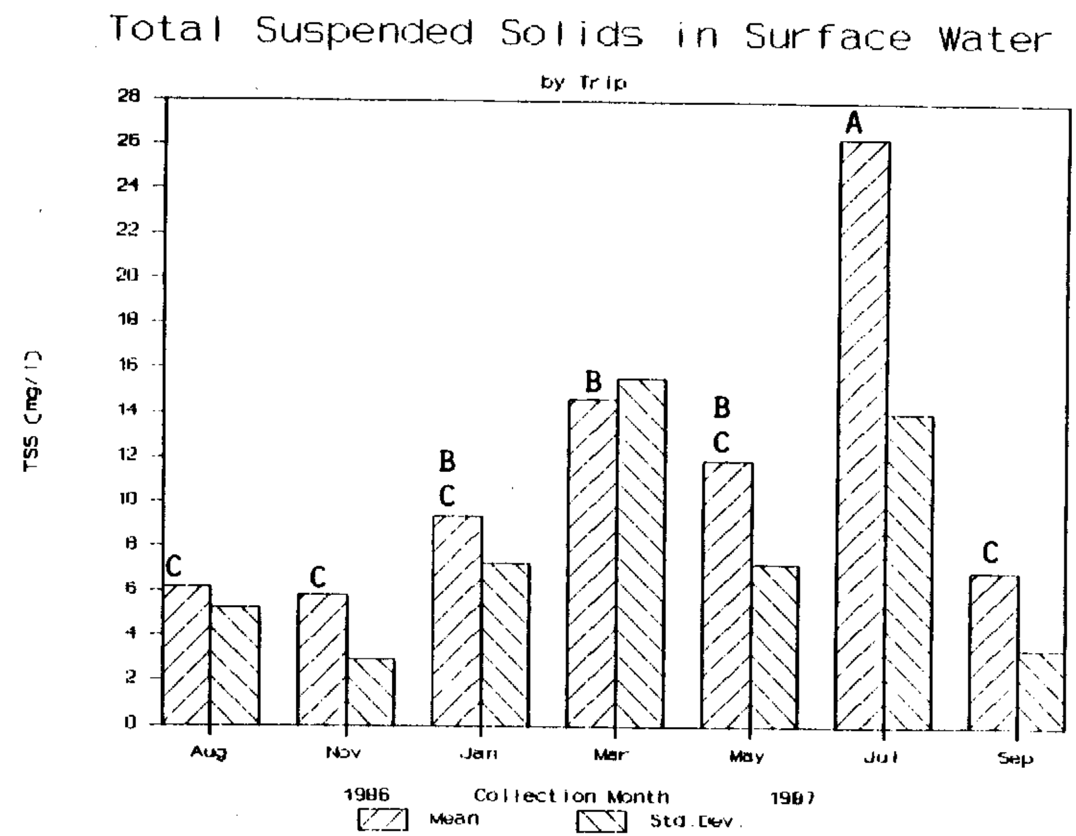
**SURFACE TSS**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .7956 |
| Location | .1919 |
| System | .7175 |
| Loc X Syst | .9635 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 27




**ANALYSIS OF VARIANCE RESULTS**

**SURFACE TSS**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0002 |
| Date | .0001 |
| Loc X Date | .0567 |

Figure 28

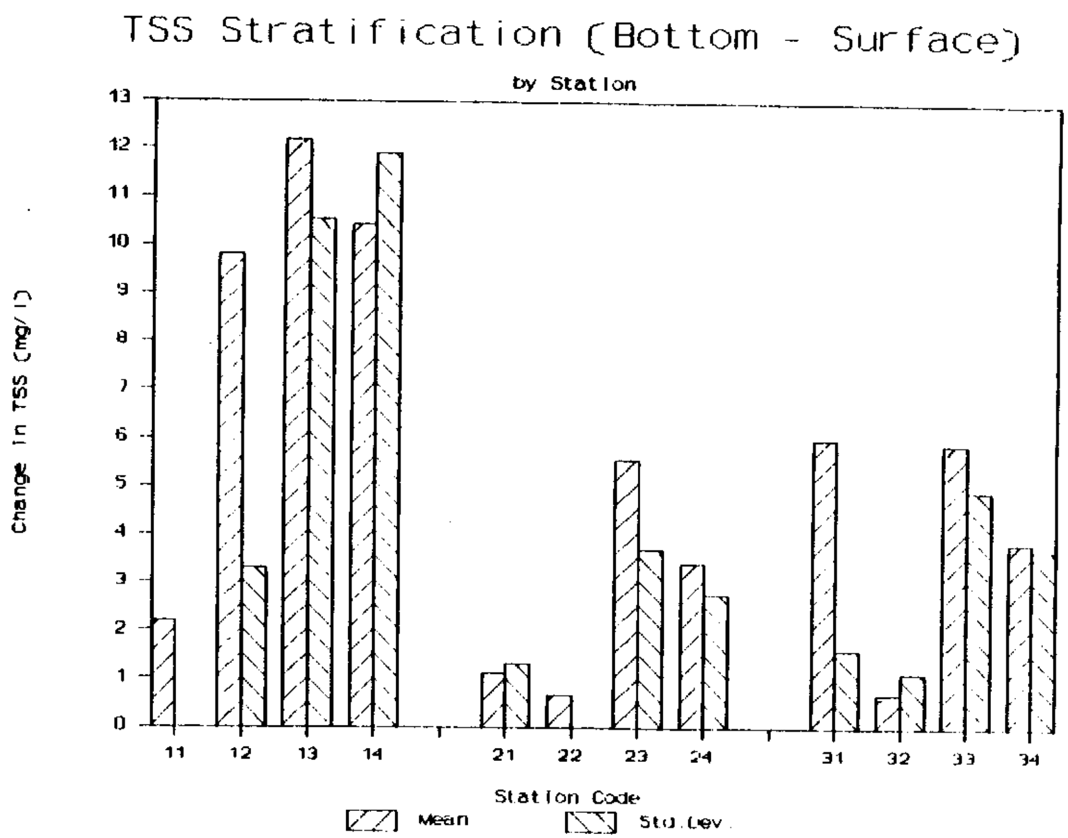
mg/l. TSS stratification did not vary significantly with location, however (Figure 29).

Suspended organic matter in surface water averaged 4.5 mg/l (38% of TSS). Means (over all trips) ranged from 2.4 mg/l at Northwest Highway Creek Pond 2 (NWHP2) to 5.75 mg/l at the mouth of Little Madeira Bay (LMBHS). As with TSS, suspended organic matter of surface water was lowest at the most upstream stations in each system (Figure 30). Again as with TSS, the ANOVA model yielded no significant effect of location, but a regression of significance level > 90% was obtained, suggesting less suspended organic matter upstream (Appendix B, Observation 23).

Mean suspended organic matter (over all stations) varied seasonally (Figure 31) from 1.6 mg/l in November 1986 to 8.8 mg/l in May 1987. Again as with TSS, in stratified water the bottom layer averaged half again higher in suspended organic matter, an average increase of 2.5 mg/l. Unlike TSS, this effect was not as consistently an increase: a decrease was recorded in 25% of the measurements. This effect did not follow a consistent upstream to downstream pattern (Figure 32).

## Dissolved Oxygen

Morning dissolved oxygen (DO) within 10 to 20 cm of the bottom averaged 5.34 mg/l, an average of 0.26 mg/l lower than that in surface water. Water tended to be more oxygen-stratified at the upstream stations, with morning oxygen being reduced in the lower layer on average by 0.50 mg/l. As illustrated in Figure 33, mean morning bottom DO (over all trips) ranged from 3.88 mg/l at Snook Creek Pond 3 (SCPD3) to 6.32 mg/l at Northwest Highwa Creek Pond 2 (NWHP2). The lowest morning DO recorded was 1.68 mg/l (25% of




**ANALYSIS OF VARIANCE RESULTS**

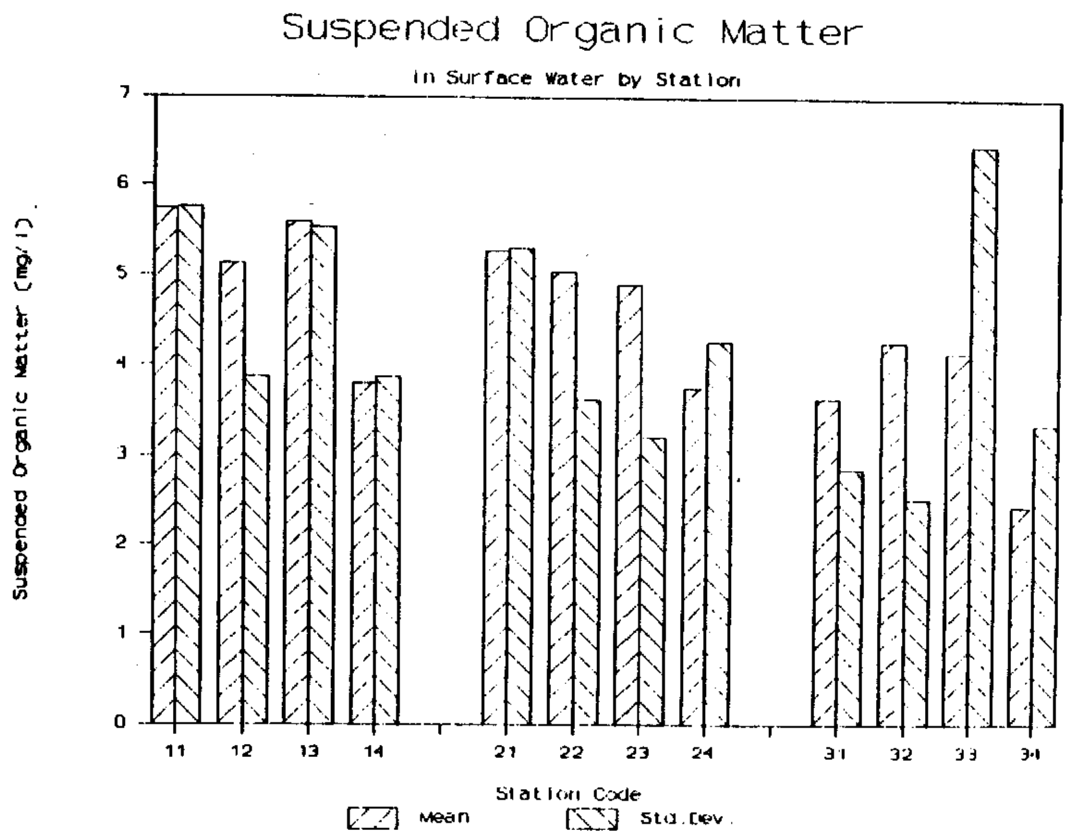
**TSS STRATIFICATION**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .7193 |
| Location | .6626 |
| System | .1169 |
| Loc X Syst | .9626 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 29




**ANALYSIS OF VARIANCE RESULTS**

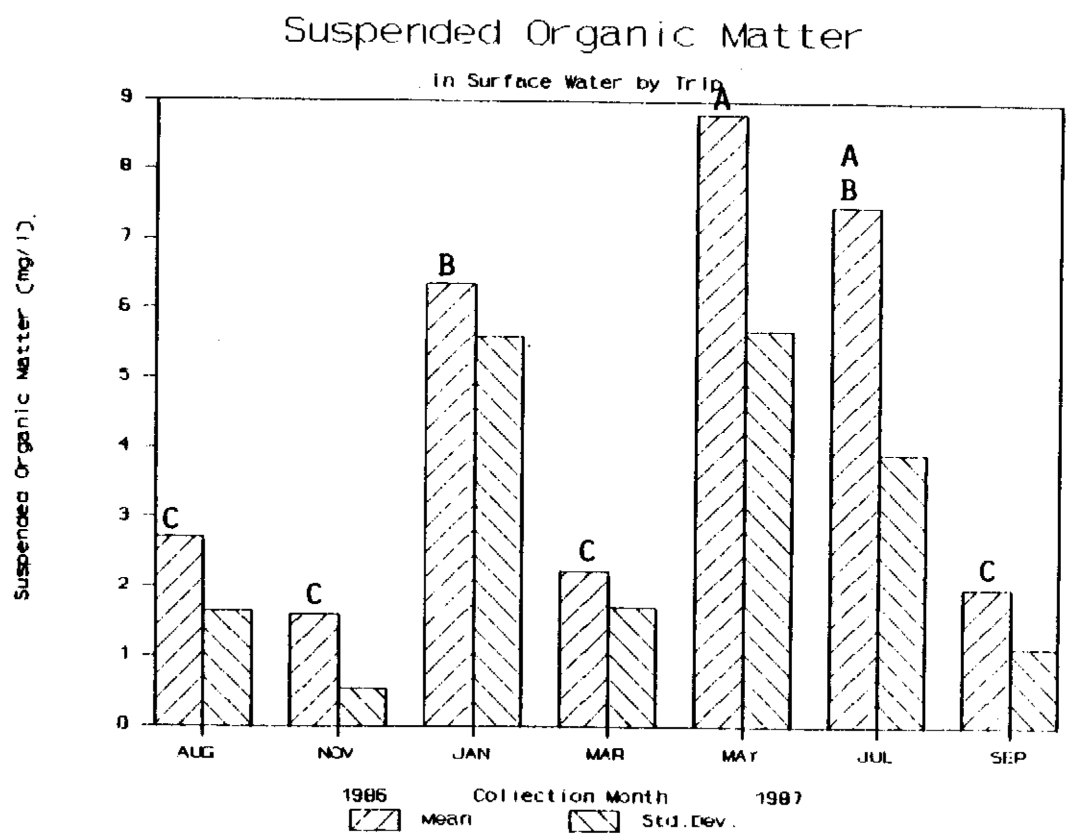
**SURFACE SUSPENDED ORG. MATTER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .9873 |
| Location | .6567 |
| System | .5177 |
| Loc X Syst | .9999 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 30

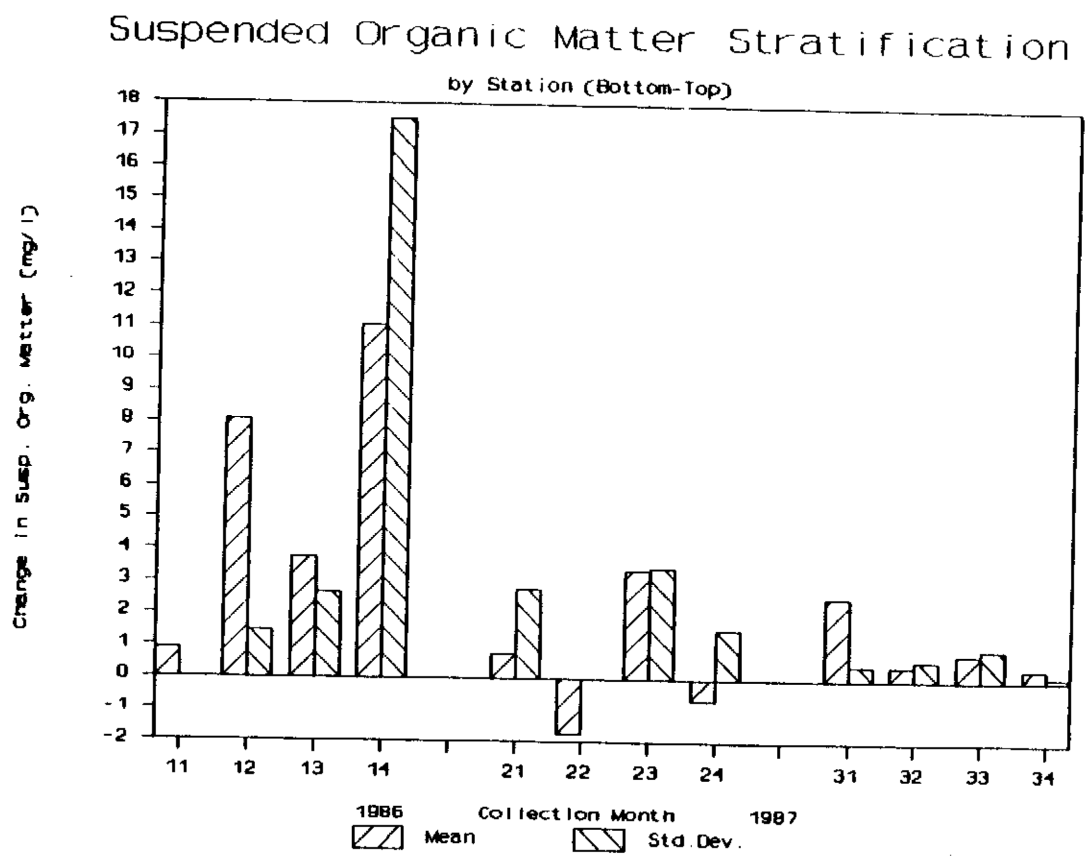



**ANALYSIS OF VARIANCE RESULTS**

**SUSPENDED ORGANIC MATTER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .0001 |

Figure 31




ANALYSIS OF VARIANCE RESULTS

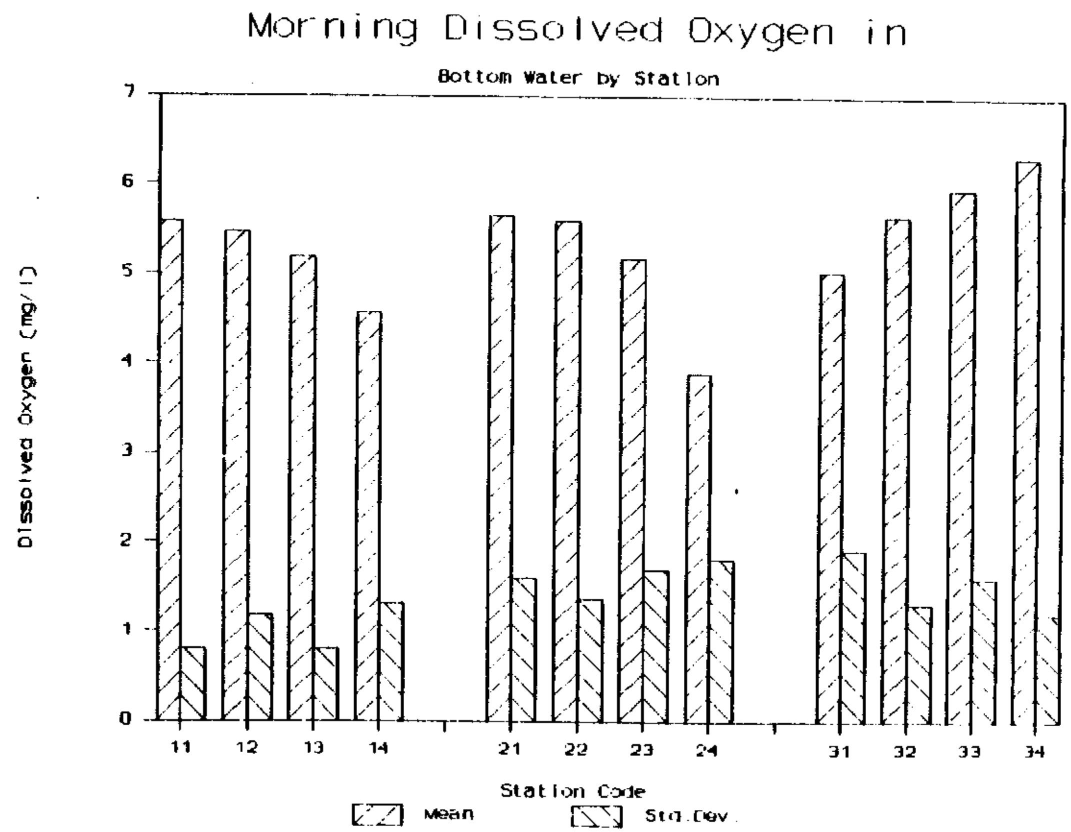
SUSP. ORG. MAT. STRATIFICATION

| Fixed Effect | Significant Probability |
|---|---|
| Model | .7912 |
| Location | .8577 |
| System | .1779 |
| Loc X Syst | .8314 |

WALLER-DUNCAN GROUPING

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 32




**ANALYSIS OF VARIANCE RESULTS**

**MORNING DISSOLVED OXYGEN**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .2980 |
| Location | .5456 |
| System | .2376 |
| Loc X Syst | .2397 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

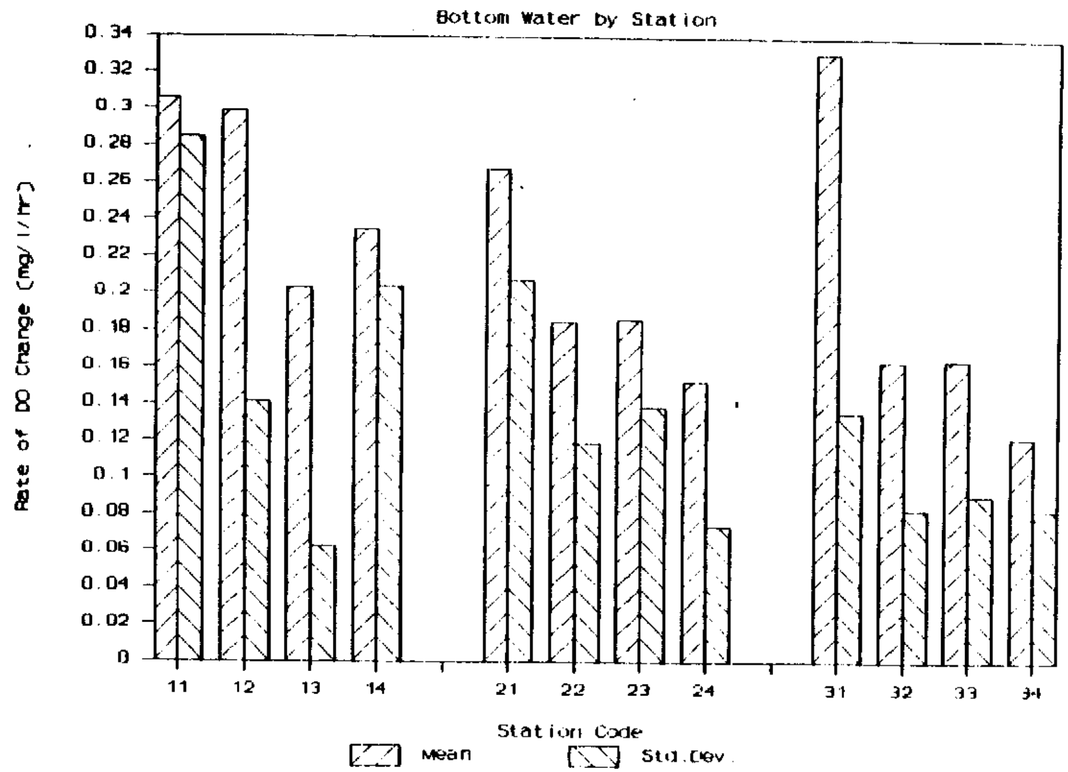
Figure 33

saturation) at SCPD3 during the November 1986 trip. The highest morning bottom DO was 9.16 mg/l (94% saturation) at Highway Creek Pond 1 (HCPD1) in January 1987. In the western and central systems, average morning oxygen increased from upstream to downstream, but in the eastern system, the opposite was true. Overall, no significant effect of location was detected.

Bottom oxygen increased during the 4 to 6 hours between measurements at each station by an average of 0.22 mg/l/h. Rates were significantly lower at upstream and at eastern stations (Figure 34; see also Appendix B, Observation 11). The lowest average rate of increase was 0.12 mg/l/h in Northwest Highway Pond 2 (NWHP2). The highest was 0.33 mg/l/h at Northeast Little Blackwater Sound (NELBS). Mean rates of increase (over all stations) varied seasonally (Figure 35). They were significantly lowest in March 1987 (0.03 mg/l/h) when oxygen actually declined at five stations during the day. Rates were highest in July 1987 at an average of 0.30 mg/l/h, but these rates were not significantly higher than any other month measured except March 1987 (Figure 35). The highest rate of increase recorded was 0.96 mg/l/h at the mouth of Little Madeira Bay (LMBHS) in August 1986. The greatest decrease recorded was -0.22 mg/l/h at Taylor River Pond 3 (TRPD3) in March 1987.

Although dissolved oxygen levels generally increased during the day at all stations, the percentage of the oxygen saturation level reached in bottom water varied systematically from upstream to outer stations (Figure 36). Mean percent saturation (over all trips) ranged from 62% at Snook Creek Pond 3 (SCPD3) to 116% at the mouth of Little Madeira Bay (LMBHS). Generally, the two upstream stations in each system did not reach saturation, while the two outermost stations met or exceeded saturation levels for DO. A significant (> 99%) regression with location was obtained for mean percent saturation

# Rate of Dissolved Oxygen Increase in




**ANALYSIS OF VARIANCE RESULTS**

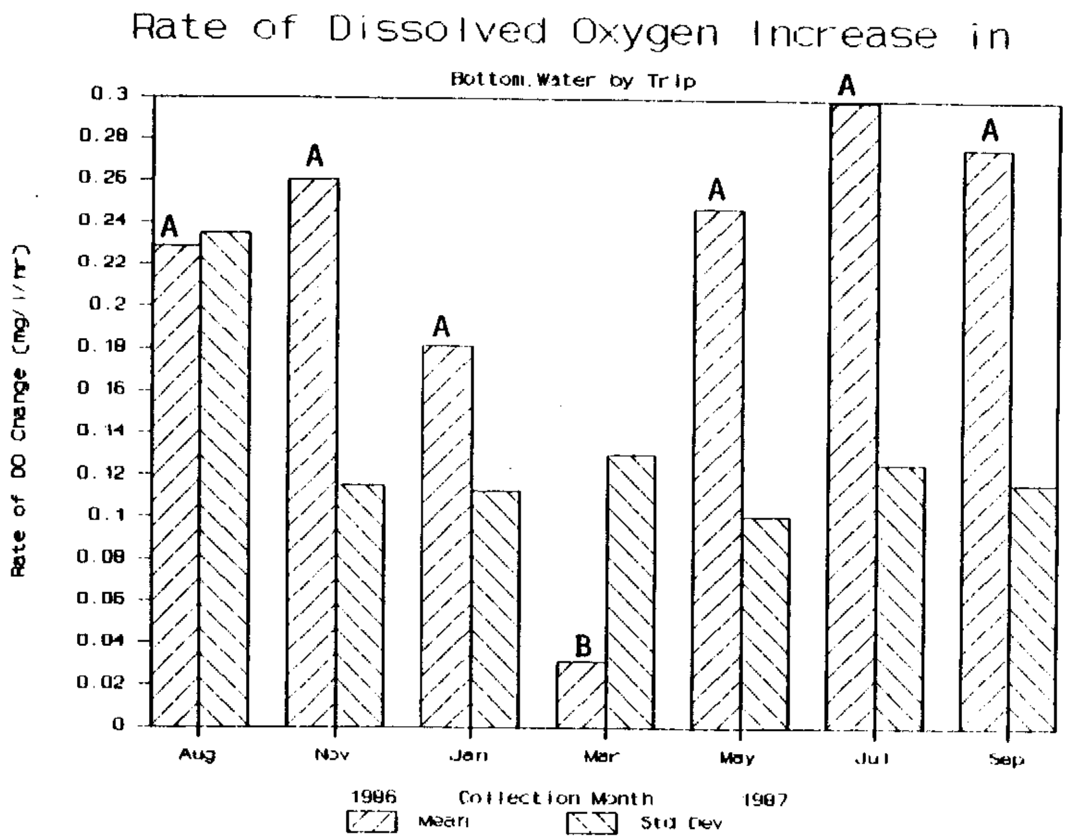
**RATE OF D.O. INCREASE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .2667 |
| Location | .0454 |
| System | .2364 |
| Loc X Syst | .8707 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | AB |
| 3 | B |
| 4 | B |

Figure 34

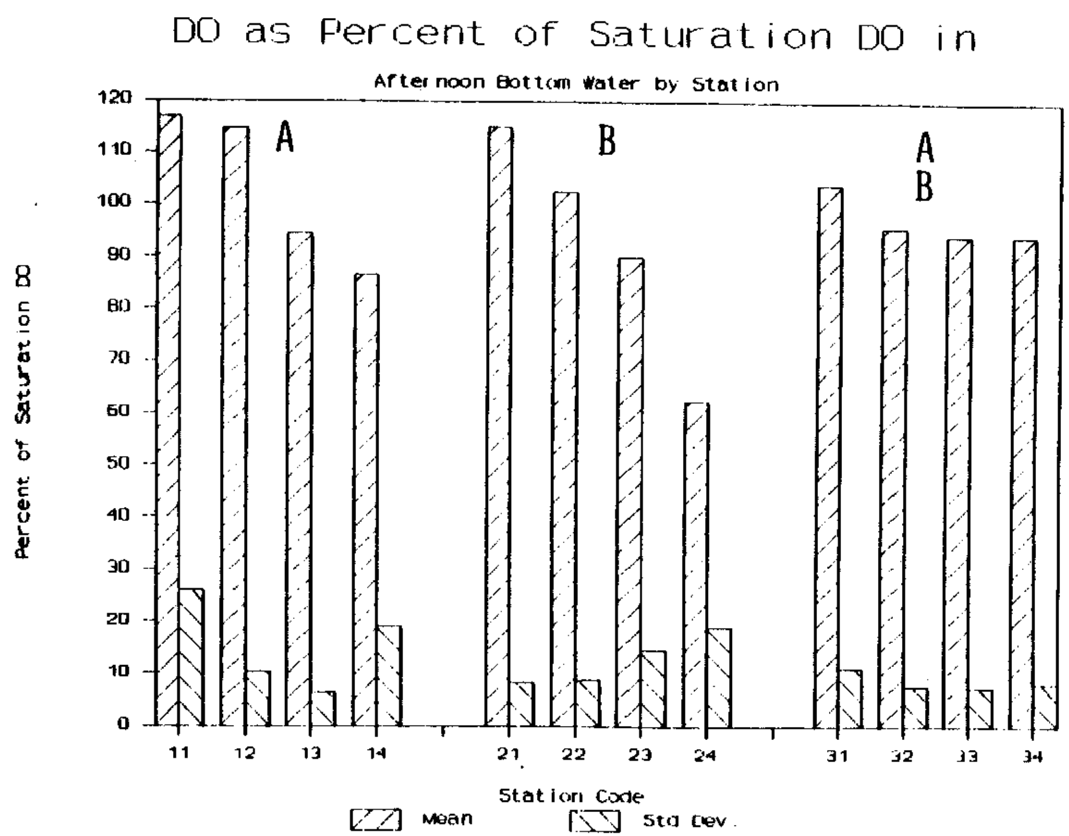



**ANALYSIS OF VARIANCE RESULTS**

**RATE OF D.O. INCREASE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0263 |
| Date | .0007 |
| Loc X Date | .4160 |

Figure 35




**ANALYSIS OF VARIANCE RESULTS**

**AFTERNOON D.O.**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .0001 |
| System | .0273 |
| Loc X Syst | .0055 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | A |
| 3 | B |
| 4 | C |

Figure 36

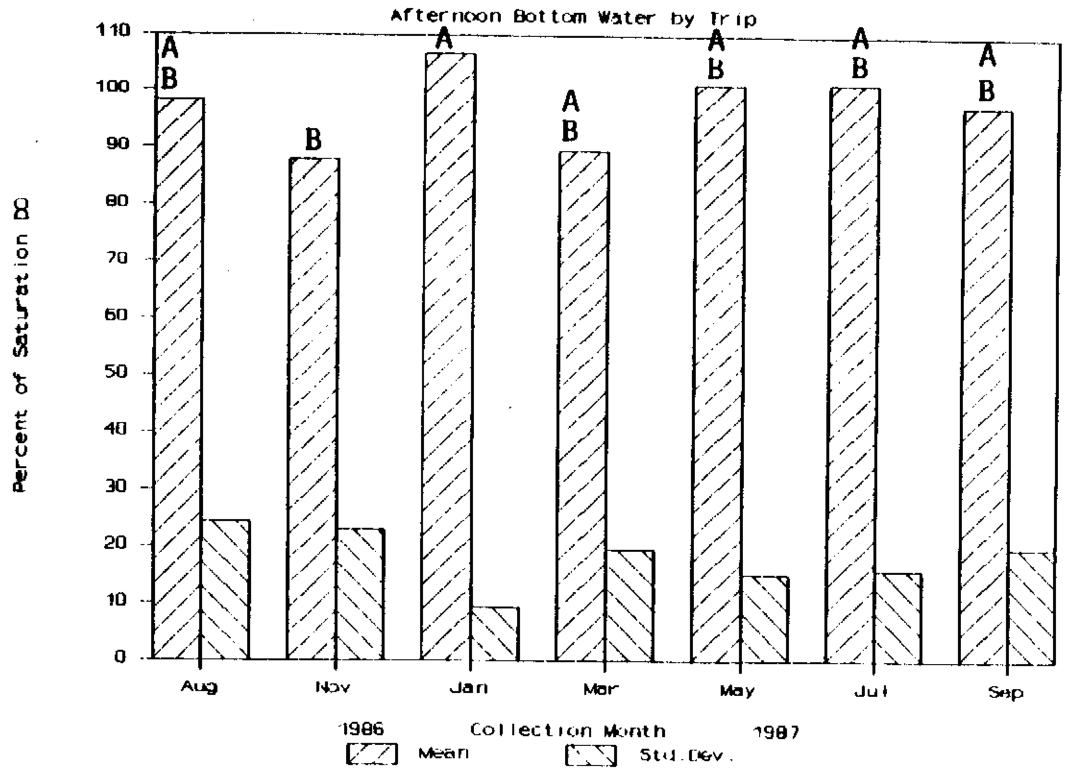
(Appendix B, Observation 6). Seasonal variation in percent saturation (over all stations) varied much less than the station-to-station means (Figure 37). Means ranged from 88% in November 1986 to 107% in January 1987. The overall average percent saturation for the later measurement of bottom water was 98%.

Diurnal Change in Dissolved Oxygen

Among the eight diurnal oxygen curves collected (Figures 38 through 45), dissolved oxygen changed by an average of 2.77 mg/l in surface water and 4.91 mg/l near the bottom. With one major exception, oxygen changed more at outer stations than at upstream stations (a bottom water average change of 3.98 mg/l at outer stations vs 1.00 mg/l at upstream stations). Oxygen changed most, however, at the innermost central station, Snook Creek Pond 3 in April 1986 (Figure 41). At this station, dissolved oxygen near the bottom increased from a low of zero mg/l at 1030 to 15.5 mg/l by 1330, and dropped to 3.31 mg/l by 0745 the following day. At the outermost central station (Northeast Trout Cove) during the same period (Figure 40), dissolved oxygen varied from a high of 8.75 mg/l at 1900 to a low of 5.95 mg/l at 0700. The least diurnally varying station measured was the upstream-most eastern station (Northwest Highway Pond 2) in July 1986, at which dissolved oxygen near the bottom varied from 5.74 mg/l at 0430 to 4.89 mg/l at 1031 (Figure 45).

During the diurnal monitoring, dissolved oxygen was often below saturation levels, especially in summer. At Taylor River Pond 2 West (TRPD2W) in May 1986 (Figure 43) and at Northeast Long Sound (NELSD) and Northwest Highway Pond 2 (NWHP2) in July 1986 (Figure 45), dissolved oxygen never exceeded saturation levels at any time during the day or night. Only

# DO as Percent of Saturation DO in




**ANALYSIS OF VARIANCE RESULTS**

**AFTERNOON D.O.**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0099 |
| Date | .1075 |
| Loc X Date | .0112 |

Figure 37

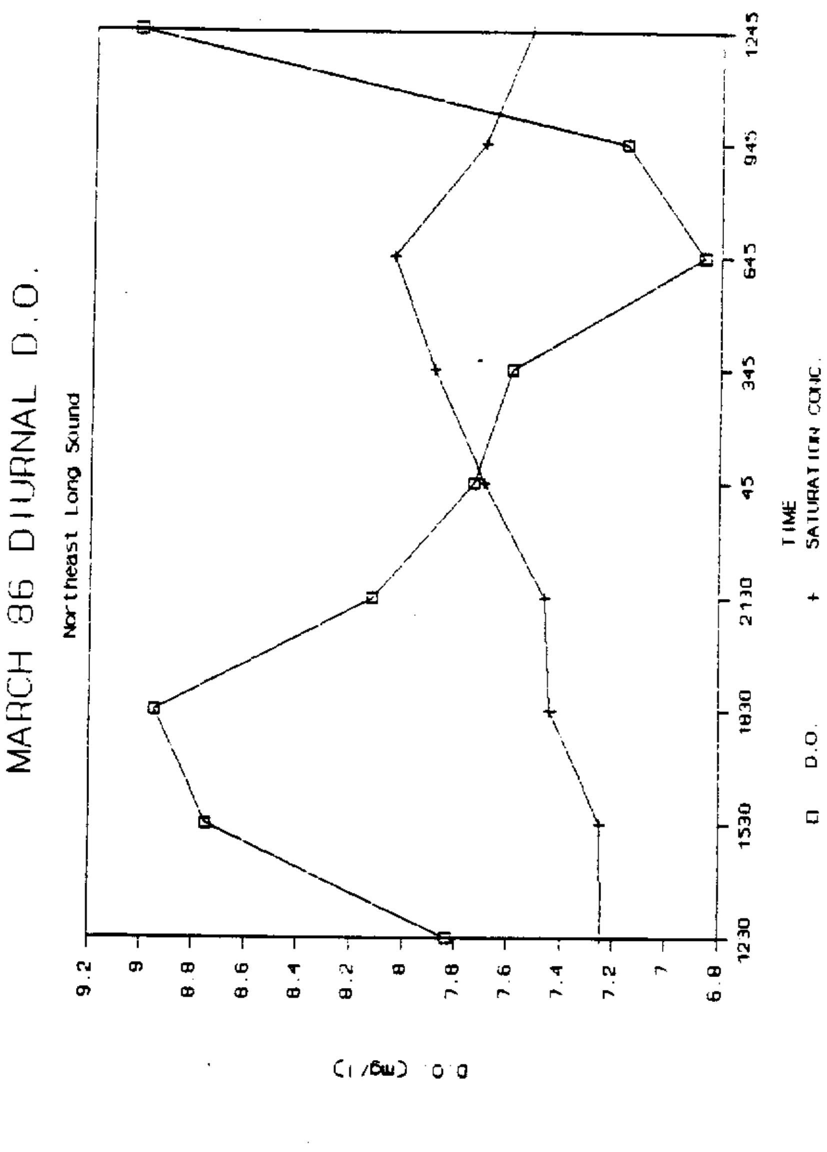

MARCH 86 DIURNAL D.O.
Northeast Long Sound
D.O. (mg/l)
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
1230
1530
1830
2130
45
345
645
945
1245
TIME
D.O.
SATURATION CONC.

Figure 38

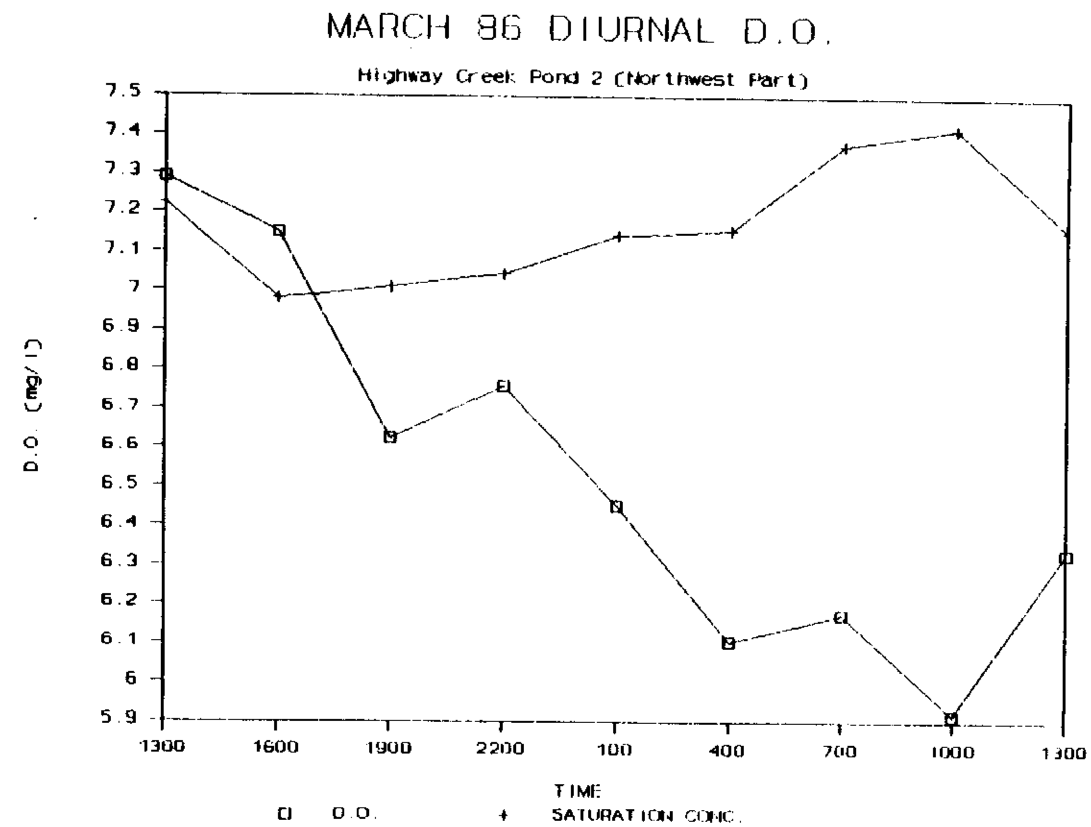
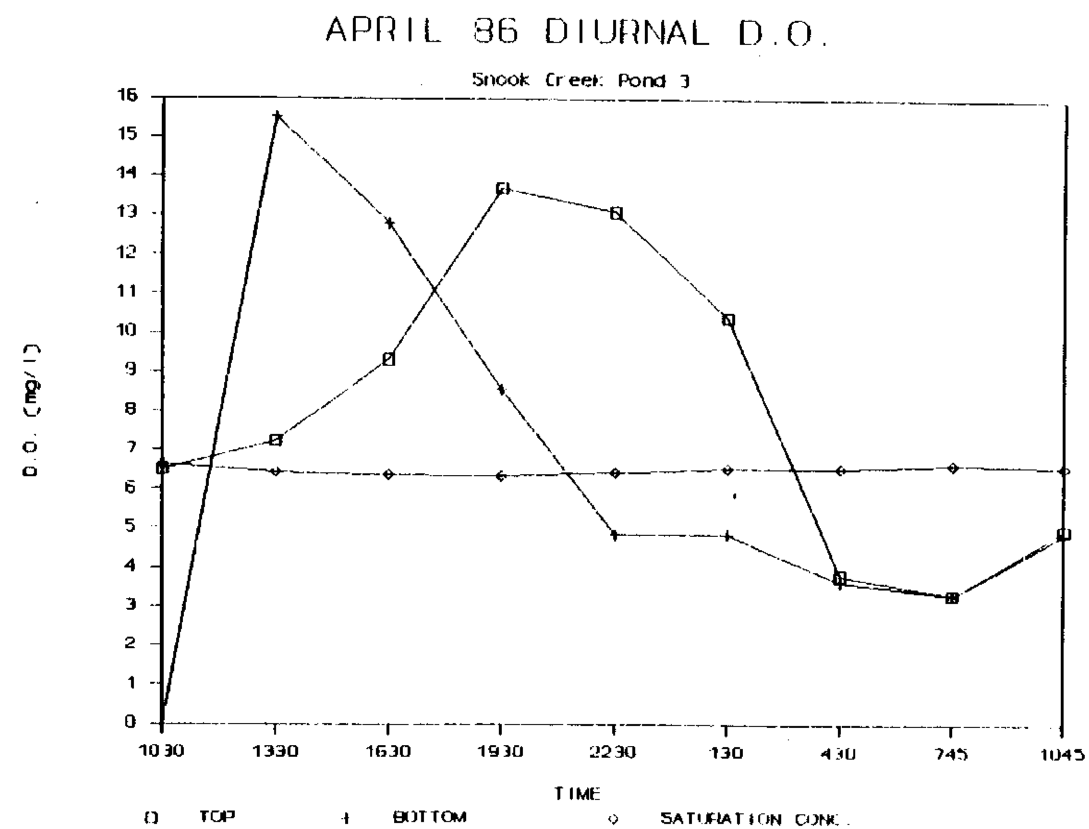

MARCH 86 DIURNAL D.O.
Highway Creek Pond 2 (Northwest Part)
D.O. (mg/l)
7.5
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
5.9
1300
1600
1900
2200
100
400
700
1000
1300
TIME
D.O.
SATURATION CONC.

Figure 39



APRIL 86 DIURNAL D.O.
Snook Creek Pond 3
D.O. (mg/l)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1030
1330
1630
1930
2230
130
430
745
1045
TIME
TOP
BOTTOM
SATURATION CONC.


Figure 41

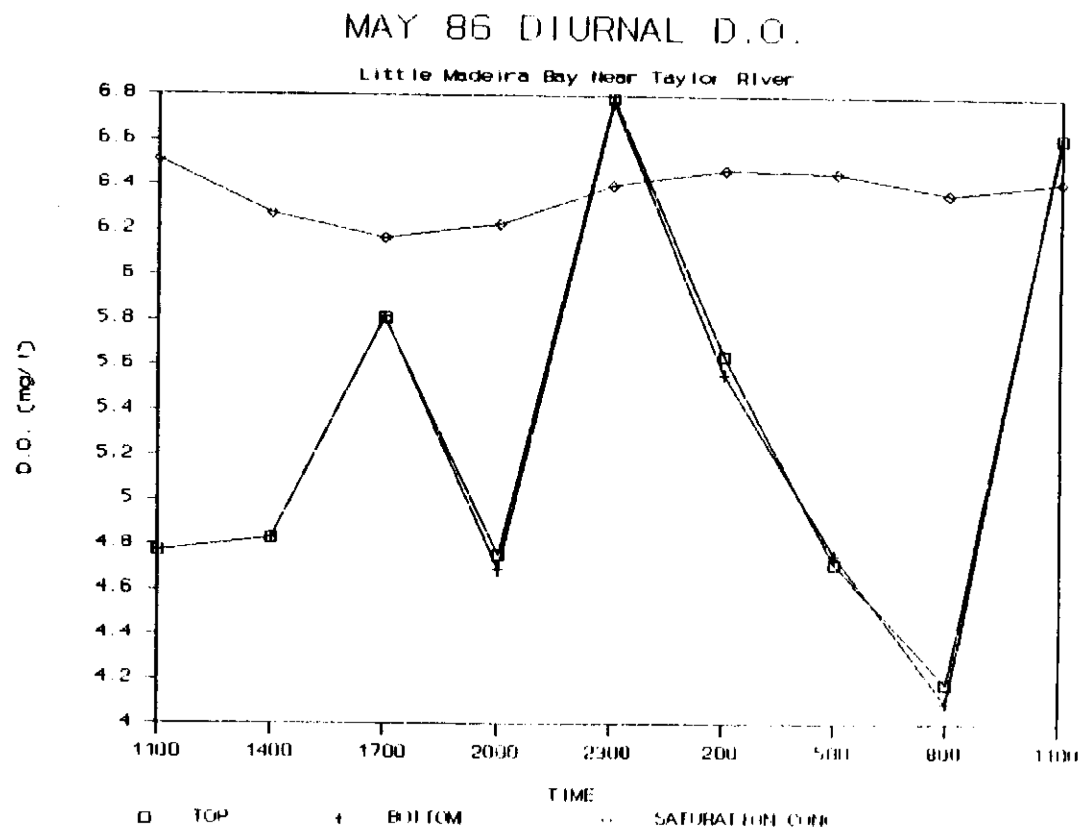

MAY 86 DIURNAL D.O.
Little Madeira Bay Near Taylor River
D.O. (mg/l)
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
1100
1400
1700
2000
2300
200
500
800
1100
TIME
TOP
BOTTOM
SATURATION CONC

Figure 42

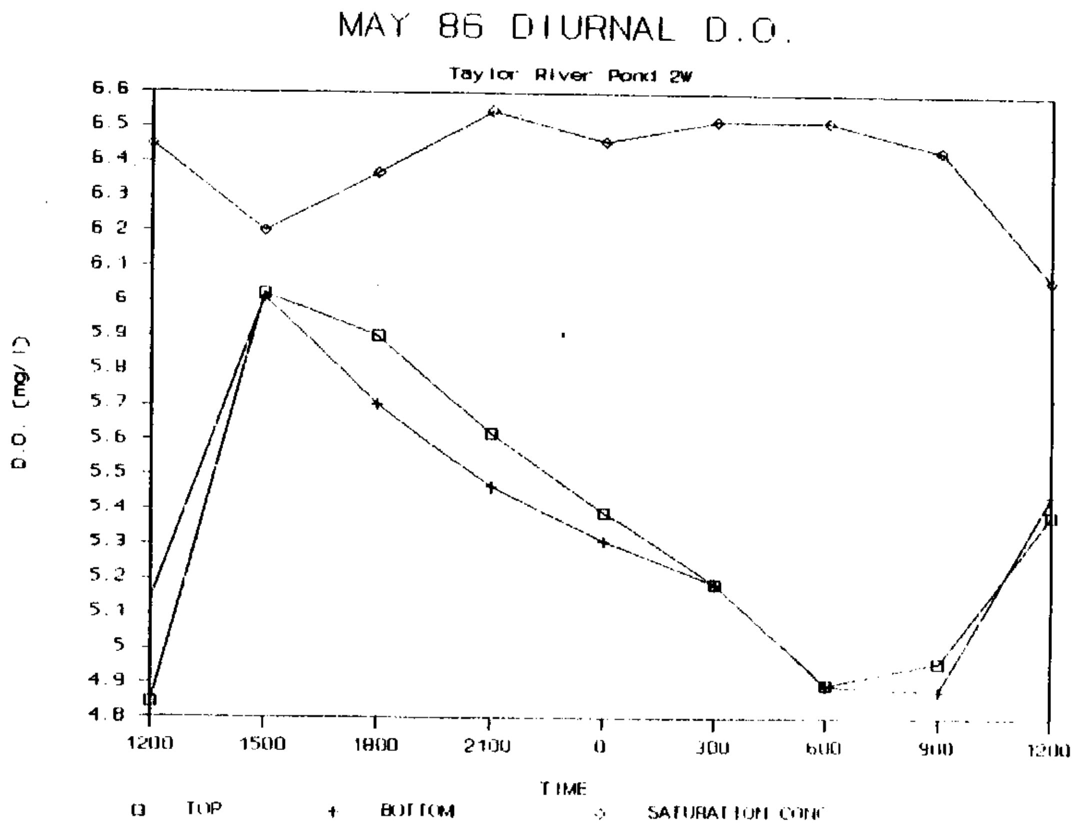

MAY 86 DIURNAL D.O.
Taylor River Pond 2W
D.O. (mg/l)
6.6
6.5
6.4
6.3
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
1200
1500
1800
2100
0
300
600
900
1200
TIME
TOP
BOTTOM
SATURATION CONC

Figure 43

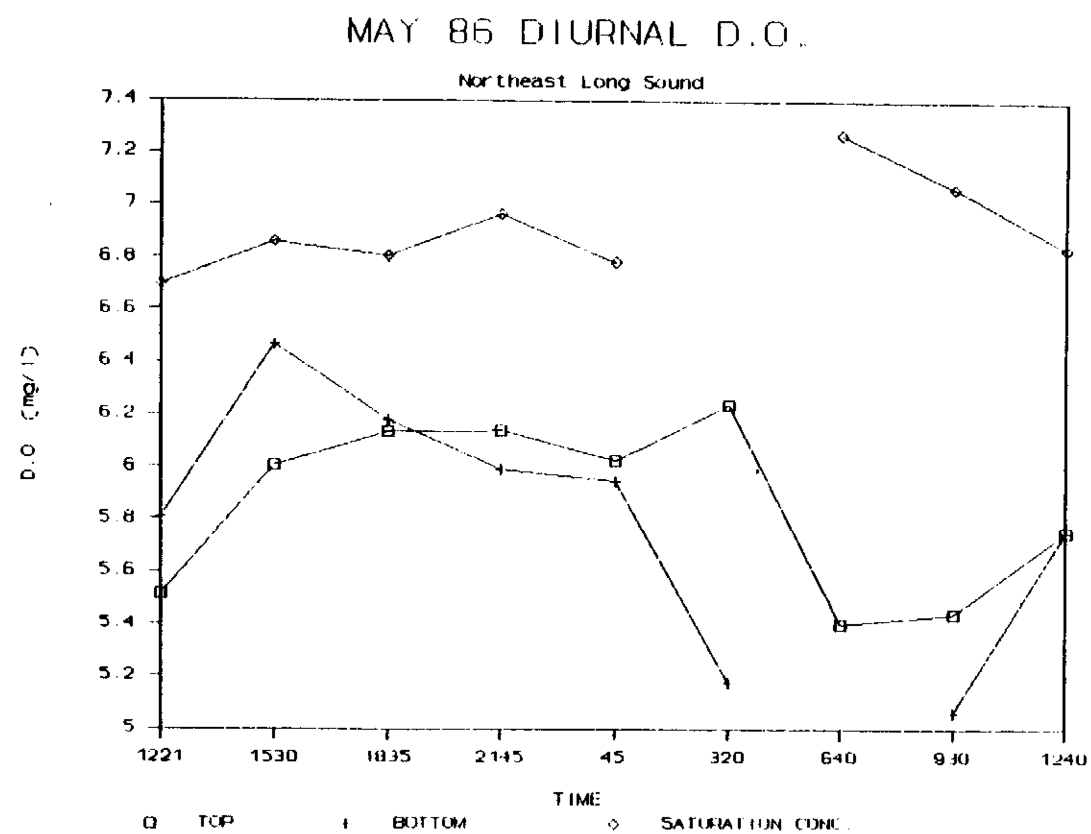

MAY 86 DIURNAL D.O.
Northeast Long Sound
D.O (mg/l)
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1221
1530
1835
2145
45
320
640
930
1240
TIME
TOP
BOTTOM
SATURATION CONC.

Figure 44

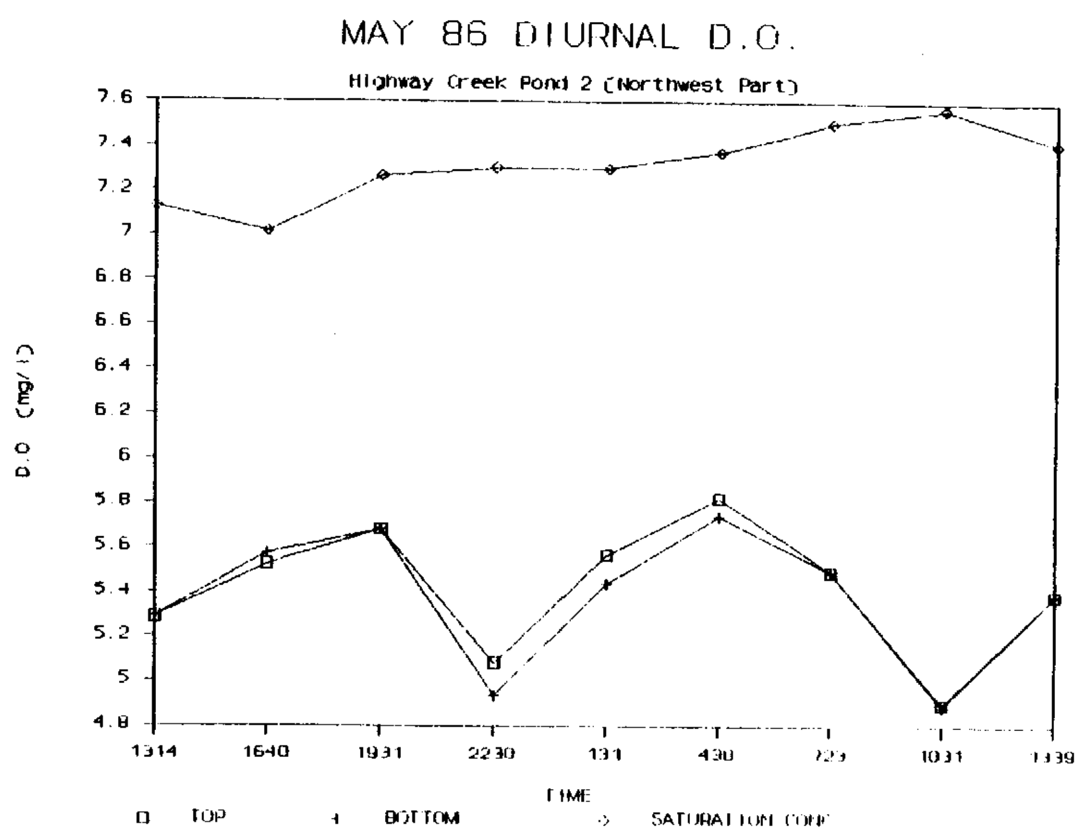

MAY 86 DIURNAL D.O.
Highway Creek Pond 2 (Northwest Part)
D.O (mg/l)
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
1314
1640
1931
2230
131
430
1031
1339
TIME
TOP
BOTTOM

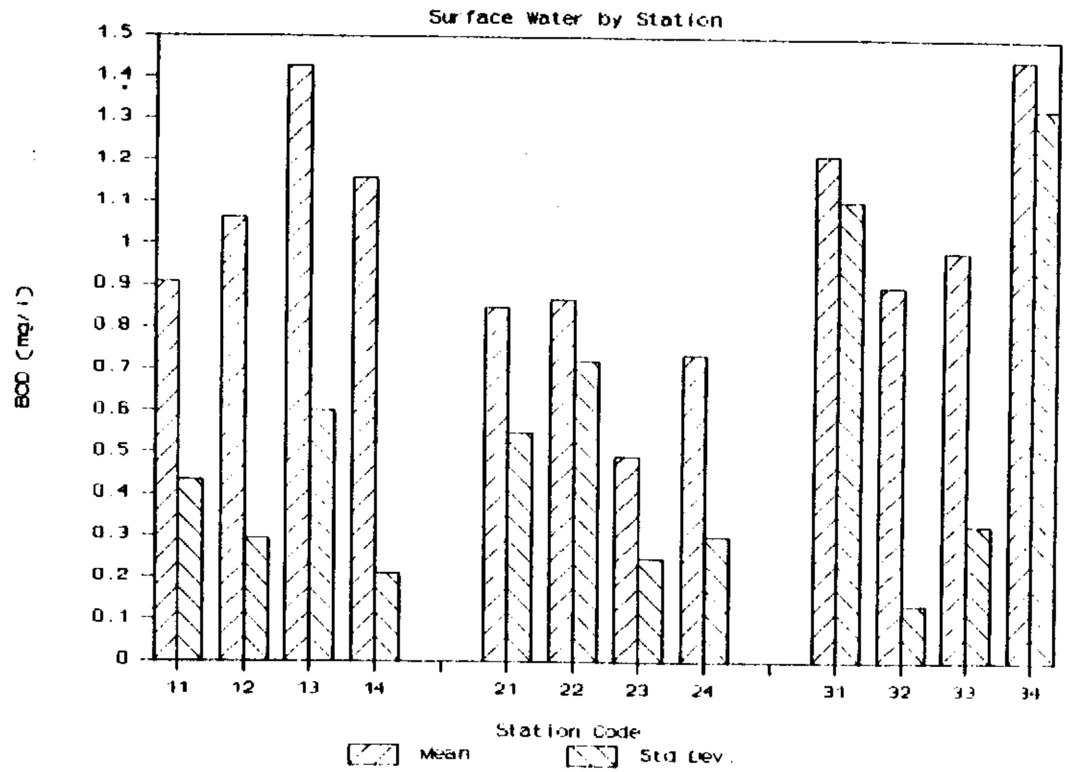
Figure 45

at one observation during the day did dissolved oxygen exceed saturation at the other May 1986 station (Little Madeira Bay at Taylor River; Figure 42). During the March 1986 and April 1986 diurnals, dissolved oxygen did exceed saturation in the afternoon (Figures 38 through 41). Concentrations above saturation occurred for more of the day at the outer stations than at the upstream stations.

Biochemical Oxygen Demand (5-Day BOD)

Biochemical oxygen demand (BOD) averaged 1.01 mg/l in surface water and 0.92 mg/l in the bottom layer of stratified water. The measure was highly variable, but the variation related well neither to upstream-downstream station position nor to time (Figures 46 and 47). Surface water at the central system stations, however, appeared to have slightly less BOD than that of the other stations. Mean surface BOD (over all trips) varied from 0.49 mg/l at Northeast Joe Bay (NEJBY) to 1.45 mg/l at Northwest Highway Creek Pond 2 (NWHP2). Surface BOD ranged from below detection limits (0.00 mg/l) at Northeast Joe Bay (NEJBY) in March 1987 to 4.33 mg/l at Northwest Highway Pond 2 (NWHP2) in September 1987. Only 8% of the 72 observations of BOD between August 1986 and September 1987 were 2.0 mg/l or above. Bottom water BOD did not range so widely. The lowest bottom-water BOD recorded was 0.31 mg/l at Northeast Trout Cove (NETCV). The highest value was 2.19 mg/l at Little Joe Bayou (LTLJB) in August 1986. Only 3% of the 35 observations of salinity-stratified water exhibited bottom-water BOD of 2.0 mg/l or above.

## Biochemical Oxygen Demand in




**ANALYSIS OF VARIANCE RESULTS**

**SURFACE BOD**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .4886 |
| Location | .8851 |
| System | .0748 |
| Loc X Syst | .6071 |

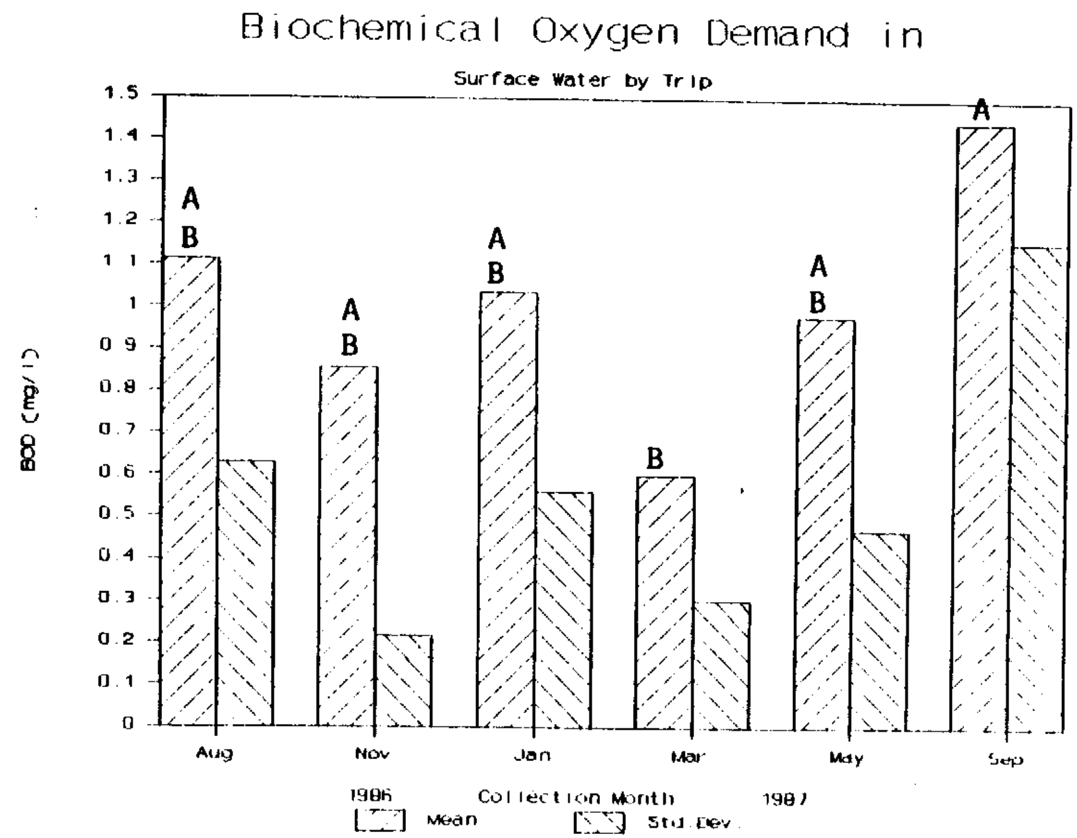
**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 46



237




**ANALYSIS OF VARIANCE RESULTS**

**SURFACE BOD**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .2525 |
| Date | .0752 |
| Loc X Date | .4770 |

Figure 47



238

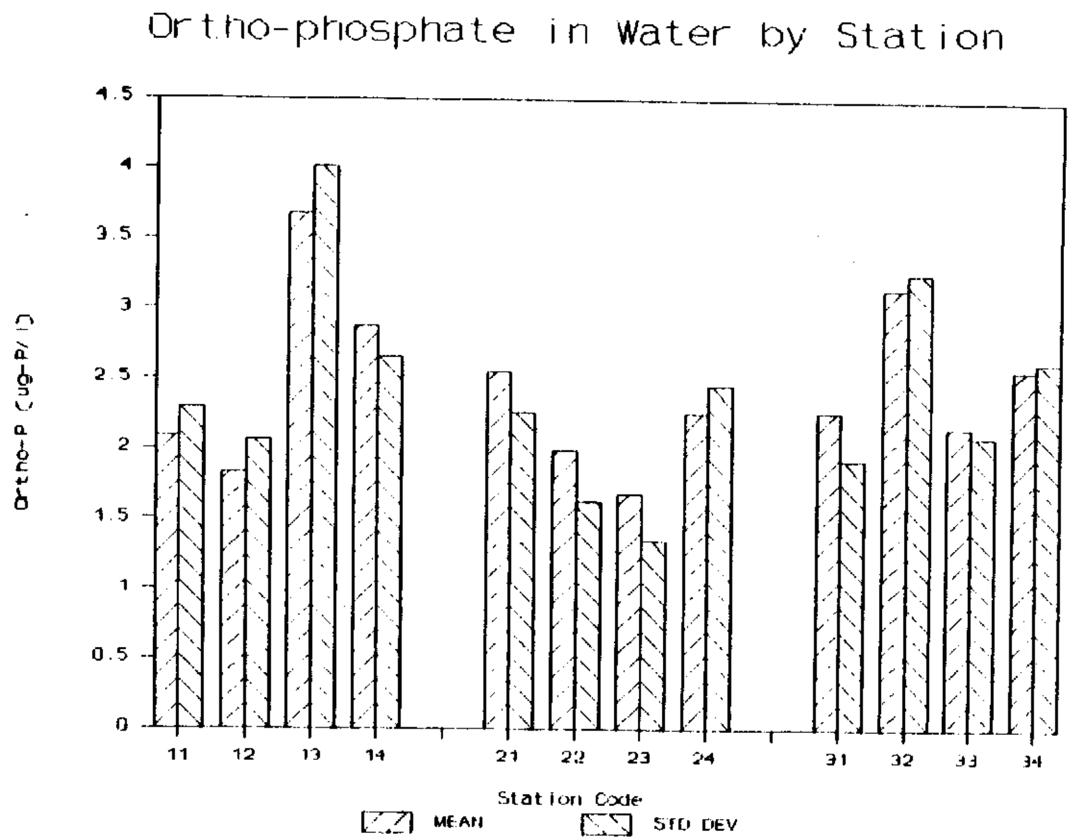
## Nutrients in Water

Phosphorus as Orthophosphate. Orthophosphate levels were very low in all samples. Levels were below detection limits (approximately 0.1 $\mu$g of P per l) on 23 out of 104 station-trip observations between April 1986 and September 1987. Mean orthophosphate concentration over all stations and trips was 2.4 $\mu$g-P/l. The highest value measured was 13.0 $\mu$g-P/l at Taylor River Pond 1 in August 1986. Although in the western system (Little Madeira Bay and Taylor River), upstream stations tended to have higher concentrations of orthophosphate than did outer stations, mean concentrations among stations (over all trips) at the other systems did not consistently vary from upstream to downstream (Figure 48). Mean concentrations (over all stations) varied seasonally (Figure 49): generally lower in summer and higher in fall and winter, with the exception of August 1987. Perhaps because of the overcast weather (which may have slowed uptake of orthophosphate by plants), August 1987 exhibited the highest mean concentration of orthophosphate measured (5.9 $\mu$g-P/l). The lowest trip mean was 0.2 $\mu$g-P/l in May 1987, a time when photosynthetic uptake was probably very high.

Total Phosphorus. Total phosphorus in water was also very low, although never below detection limits. Total phosphorus averaged about 6.4 times the concentration of phosphorus as orthophosphate. Values ranged from 2.0 $\mu$g/l at Northeast Little Blackwater Sound (NELBS) in May 1986 and again in May 1987, to a high of 101.0 $\mu$g/l at Highway Creek Pond 1 in September 1987. The overall mean for stations and dates was 15.6 $\mu$g/l. Total phosphorus did not vary significantly (by the ANOVA model) from upstream to downstream. The western system, however, had greater phosphorus at upstream stations. Also, the highest station means in each system were at one of the



239




**ANALYSIS OF VARIANCE RESULTS**

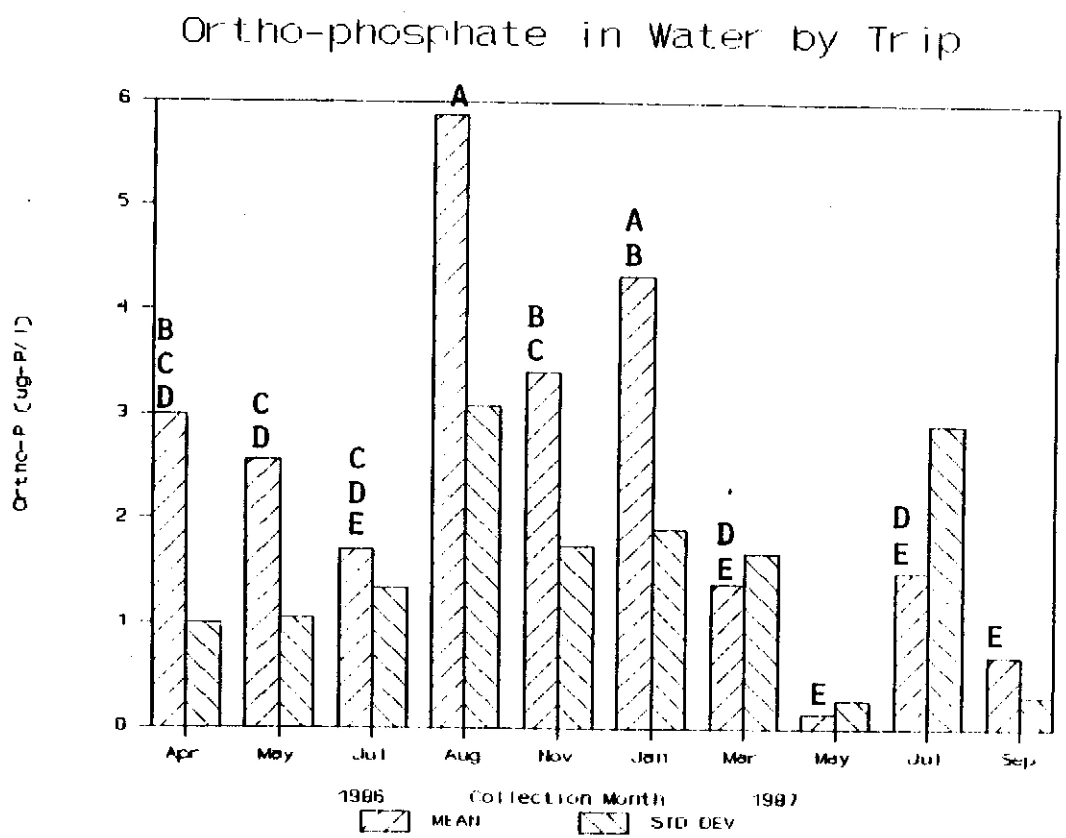
**ORTHO-PHOSPHATE IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .9523 |
| Location | .9822 |
| System | .6924 |
| Loc X Syst | .7421 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 48




**ANALYSIS OF VARIANCE RESULTS**

**ORTHO-PHOSPHATE IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .6738 |

Figure 49

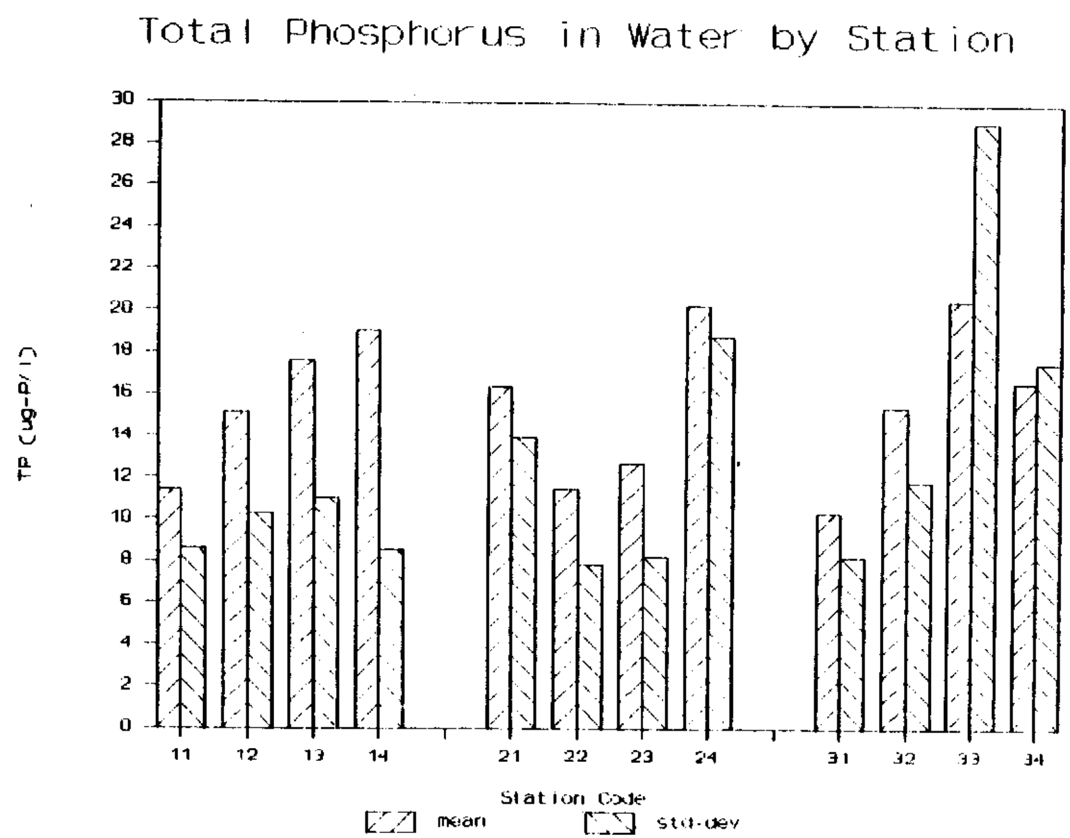
two most upstream stations and the lowest mean was at one of the two outermost stations (Figure 50). In fact, a significant (> 95%) regression with location was obtained for mean total phosphorus, suggesting greater phosphorus upstream (Appendix B, Observation 14). The lowest station mean was 10.4 μg/l at Northeast Little Blackwater Sound. The highest was 20.6 at Highway Creek Pond 1. The seasonal pattern of total phosphorus (Figure 51) is a statistically significant general increase (by eight fold) during the project period from a low of 5.4 μg/l in April 1986 to a high of 44.4 μg/l in September 1987.

Nitrogen as Ammonium. Ammonium levels were considerably higher than those of either orthophosphate or total phosphorus. Values ranged from 11.0 μg-N/l at Northeast Little Blackwater Sound (NELBS) in May 1986 to 370.0 μg-N/l at Snook Creek Pond 3 (SCPD3) in May 1987. The overall station-trip mean was 97.2 μg-N/l. No significant effect of location or system was detected for ammonium concentration by the ANOVA model results reported in Figure 52, however, a possible relationship (significance level > 90%) was detected between mean ammonium concentration and location in a regression analysis, suggesting greater ammonium upstream (Appendix B, Observation 21). Furthermore, a significant (> 95%) regression with location was obtained for standard deviation of ammonium concentration, indicating greater variability upstream (Appendix B, Observation 19).

The highest station mean (over all trips) was 141.8 μg-N/l at Snook Creek Pond 3 and the lowest was 51.9 μg-N/l at Northeast Little Blackwater Sound. As shown in Figure 53, ammonium concentrations generally increased over the study period from a mean low (over all stations) of 40.5 μg-N/l in April 1986 to a mean high of 171.7 μg-N/l in July 1987. Ammonium concentra-



942




**ANALYSIS OF VARIANCE RESULTS**

**TOTAL PHOSPHORUS IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .9018 |
| Location | .4485 |
| System | .9705 |
| Loc X Syst | .8412 |

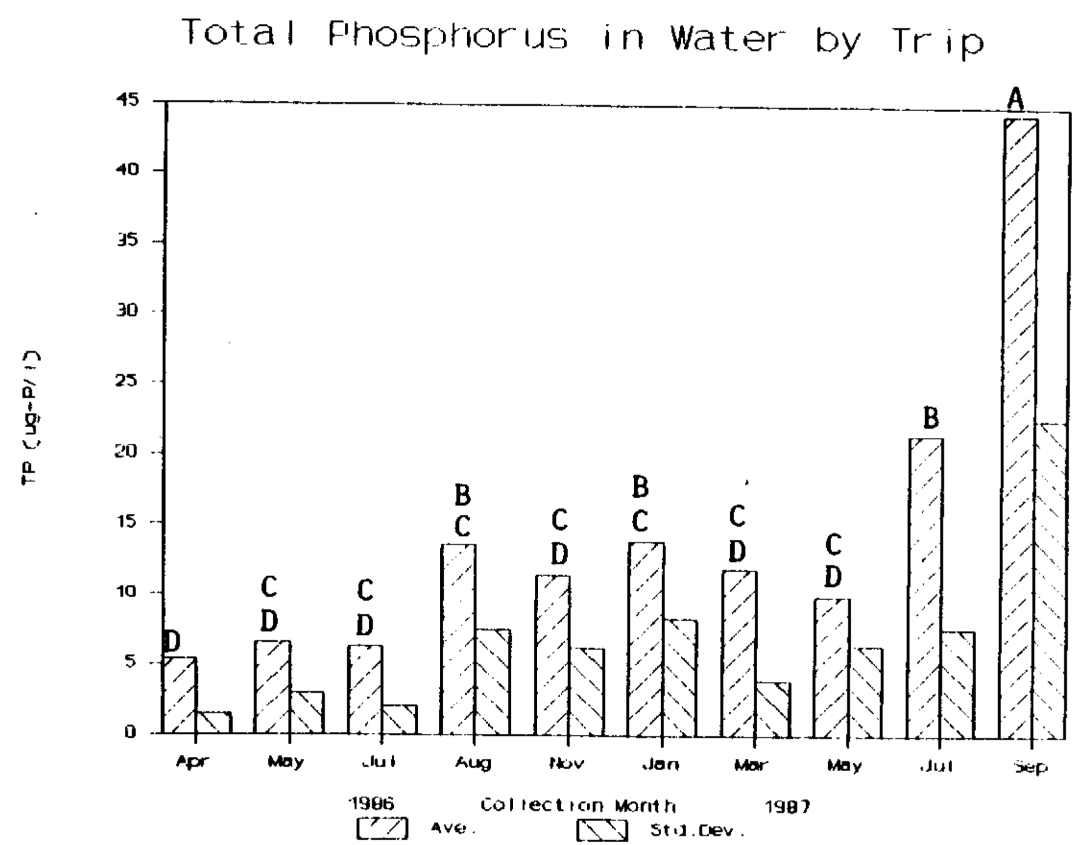
**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 50



243




**ANALYSIS OF VARIANCE RESULTS**

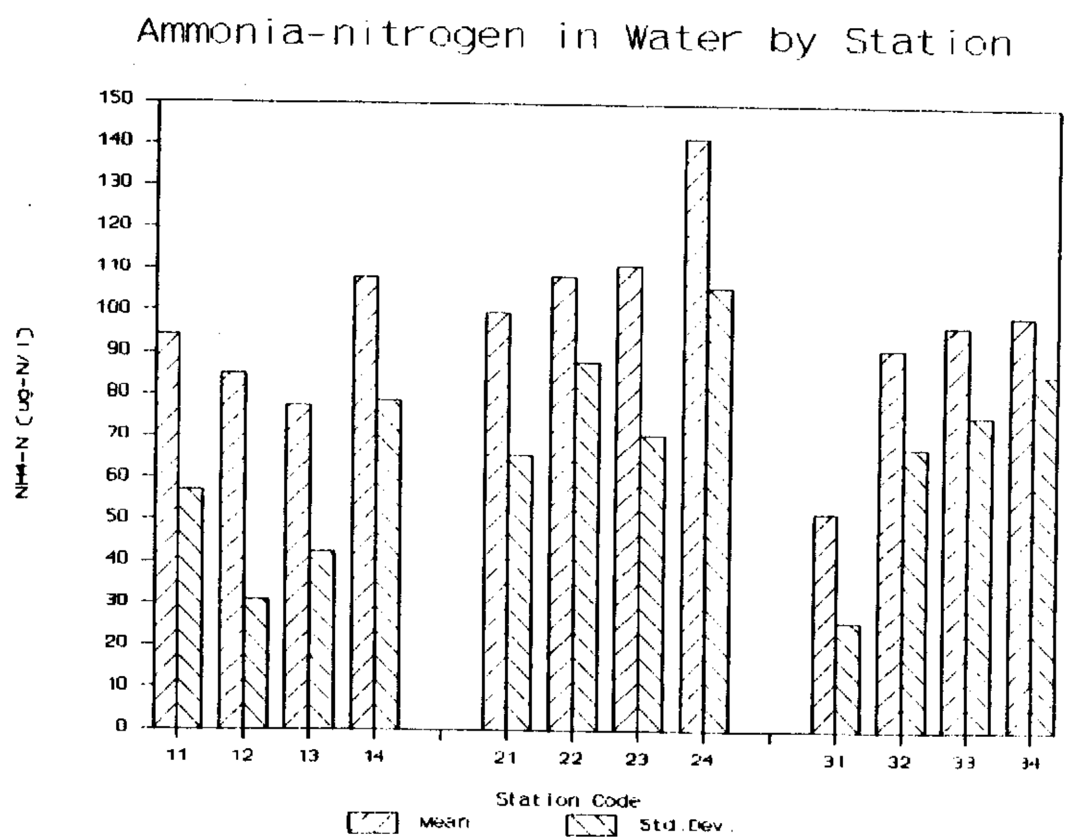
**TOTAL PHOSPHORUS IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .2857 |

Figure 51



244




**ANALYSIS OF VARIANCE RESULTS**

**AMMONIA-NITROGEN IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .6885 |
| Location | .3819 |
| System | .2020 |
| Loc X Syst | .9272 |

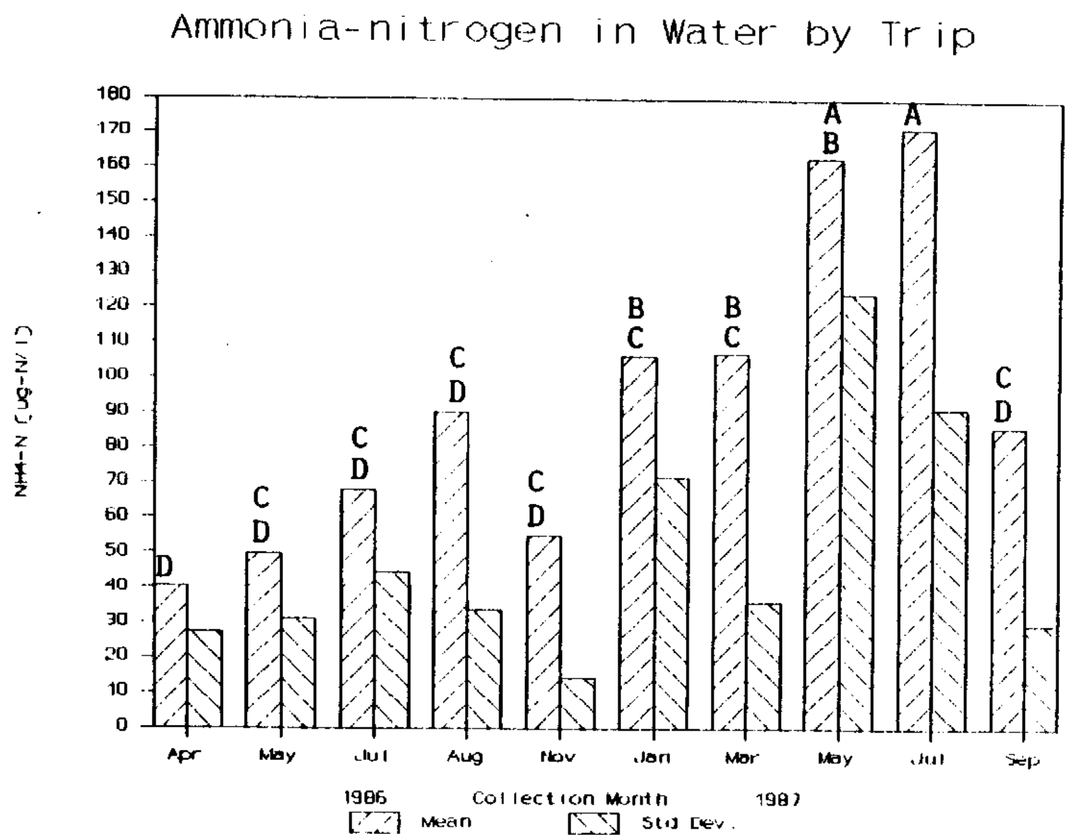
**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 52



245




**ANALYSIS OF VARIANCE RESULTS**

**AMMONIA-NITROGEN IN WATER**

| Fixed Effect | Significant Probability |
| --- | --- |
| Model | .0699 |
| Date | .0001 |
| Loc X Date | .9161 |

Figure 53



246

tions reached a sub-maximum in August 1987 (90.4 μg-N/l) followed by a sub-minimum in November 1987 (55.0 μg-N/l). Ammonium concentration also dropped considerably in September 1987 (86.2 μg-N/l) the trip following the July 1987 maximum.

Total Nitrogen. Total nitrogen in water was in much greater quantity than nitrogen as ammonium: about 13.6 times. Total nitrogen averaged 1.33 mg/l and ranged from a low of 0.30 mg/l at Northwest Highway Pond 2 (NWHP2) in January 1987 to 4.09 mg/l at Snook Creek Pond 3 (SCPD3) in July 1987. No consistent upstream to downstream or east to west pattern was apparent for total nitrogen in the ANOVA model results that accompany Figure 54, however, regressions with location of the mean and standard deviation values for each station indicated significantly greater and more variable total nitrogen upstream (Appendix B, Observations 17 and 18).

Total nitrogen increased throughout the study period, but not as dramatically as total phosphorus and ammonium, and with more pronounced seasonal fluctuations (Figure 55). Mean total nitrogen (over all stations) doubled from a low of 0.85 mg/l in April 1986 to a high of 1.88 mg/l in July 1987. Generally however, total nitrogen was higher in summer and lower from fall to spring.

Ratio of Nitrogen to Phosphorus. The ratio of atoms of total nitrogen to atoms of total phosphorus in water (N:P) can be compared to Redfield's Ratio of 16:1, the ratio he found in open-ocean water and plankton in the North Atlantic (Redfield et al. 1963). This ratio was said to be the average natural balanced nutrient medium in a system that depends primarily on recycling of nutrients to meet production demands. Ratios in an aquatic ecosystem that considerably deviate from this standard ratio may indicate



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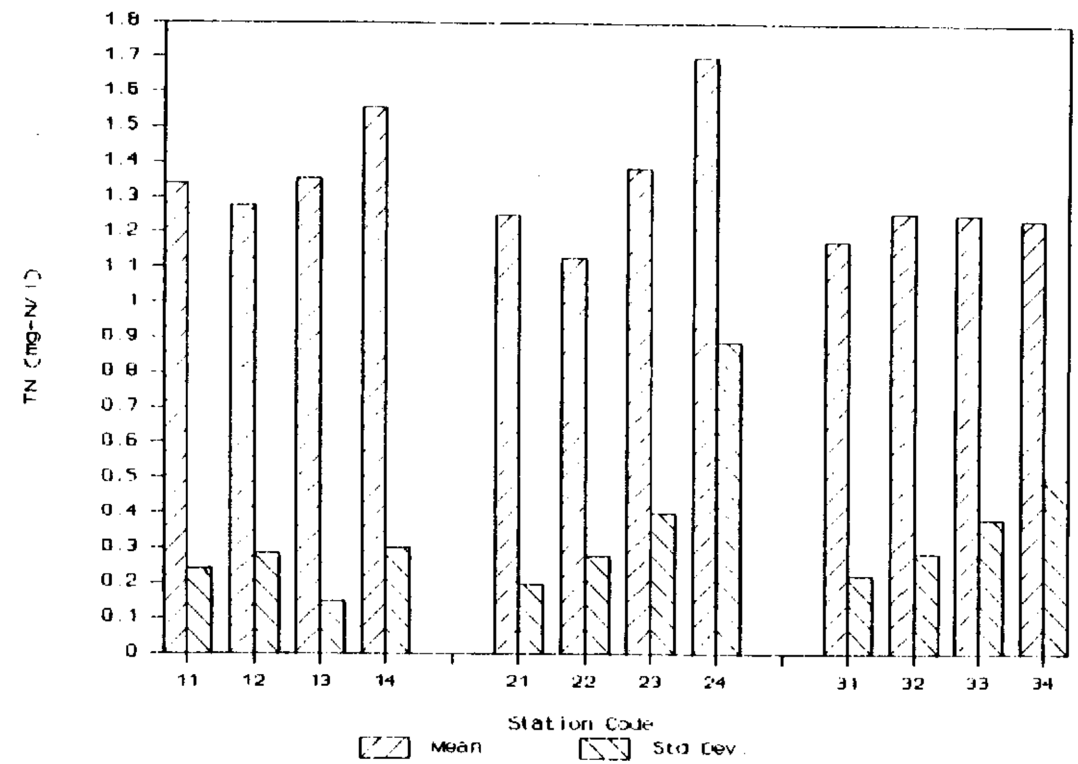
## Total Nitrogen in Water by Station




**ANALYSIS OF VARIANCE RESULTS**

**TOTAL NITROGEN IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .2328 |
| Location | .0989 |
| System | .2374 |
| Loc X Syst | .5477 |

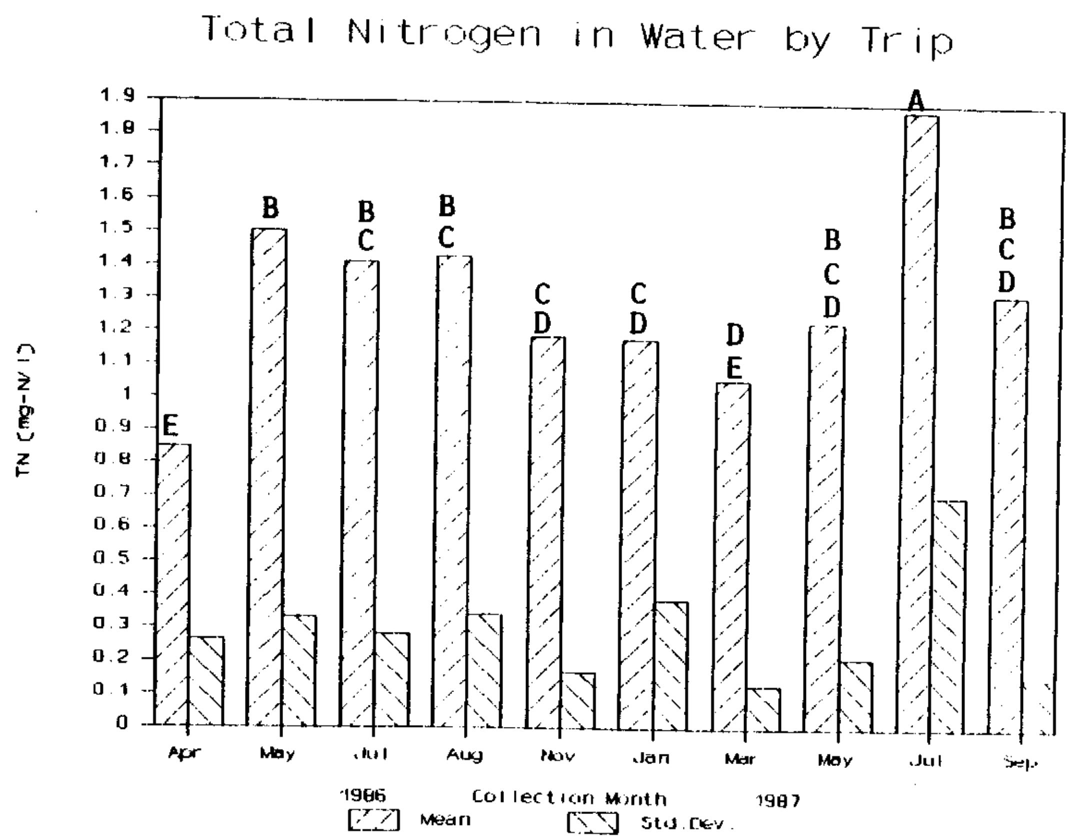
**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | AB |
| 2 | B |
| 3 | AB |
| 4 | A |

Figure 54



248




**ANALYSIS OF VARIANCE RESULTS**

**TOTAL NITROGEN IN WATER**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0002 |
| Date | .0001 |
| Loc X Date | .1219 |

Figure 55

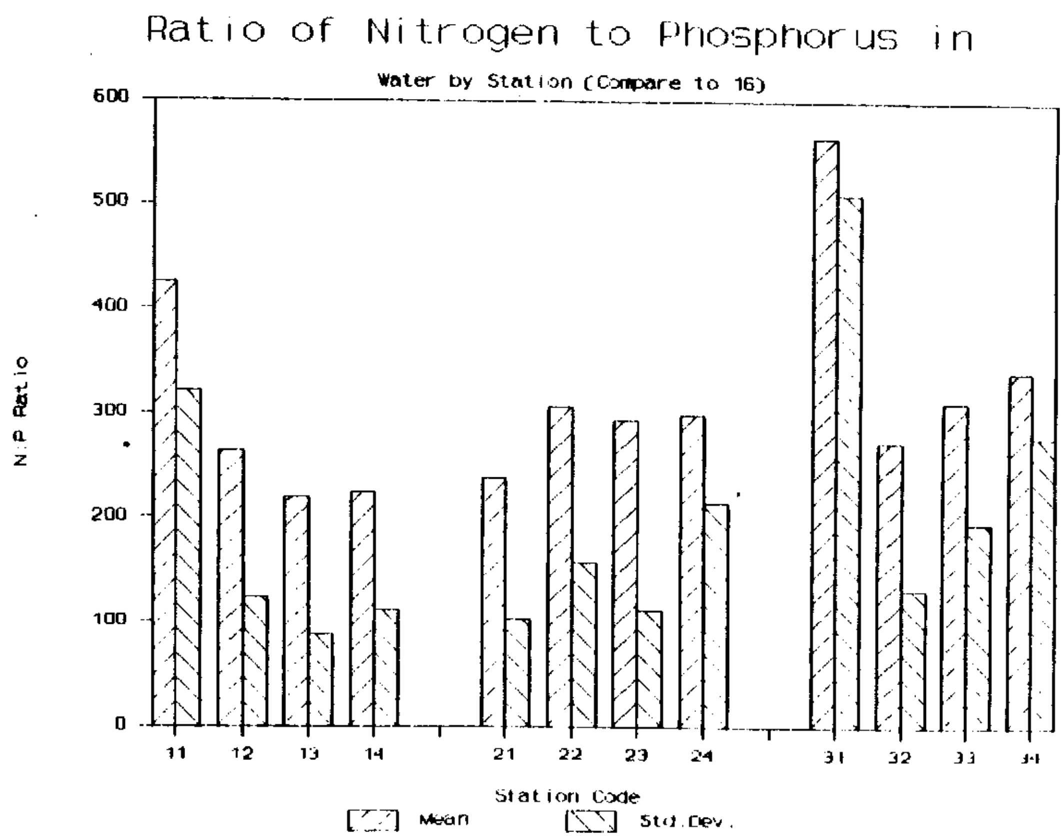
249

growth limitation by the nutrient in lower relative amount (Valiela 1984). This likelihood is presumably greater for greater deviations. The N:P values at the stations in northeast Florida Bay averaged 313 and ranged from a low of 27 at Highway Creek Pond 1 (HCPD1) in September 1987 to a high of 1517 at Northeast Little Blackwater Sound (NELBS) in May 1986. These values indicate considerable excess of nitrogen, and therefore a likely phosphorus limitation in water. Station means ranged from lows of 220 and 224 at Taylor River Pond 1 (TRPD1) and Taylor River Pond 3 (TRPD3) to a high of 564 at Northeast Little Blackwater Sound (NELBS). No consistent east-to-west or upstream-to-outer station patterns were detected, though the two highest station means were at outer stations (Figure 56). Trip mean ratios (over all stations) were highest in May 1986 (664) and lowest in September 1987 (82), with a sub-minimum in March 1987 (223) and a sub-maximum in May 1987 (407), indicating some possible seasonal pattern of lower relative levels of phosphorus in early summer (Figure 57).

## Submerged Vegetation

### Dry Weight per Square Meter

With the exception of Snook Creek stations in the earliest trips (March and April 1986) and again in November 1986, the total dry weight of above and below-ground plant material collected at each station was always much greater at outer stations than at upstream stations (Figure 58). At the outermost stations in all three systems, dry weight was 10 to 100 times greater than at the two upstream stations in each system. Except in the western system, the next-to-outermost station was intermediate in dry weight. A significant




**ANALYSIS OF VARIANCE RESULTS**

**NITROGEN TO PHOSPHORUS RATIO**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .1870 |
| Location | .1238 |
| System | .2489 |
| Loc X Syst | .3645 |

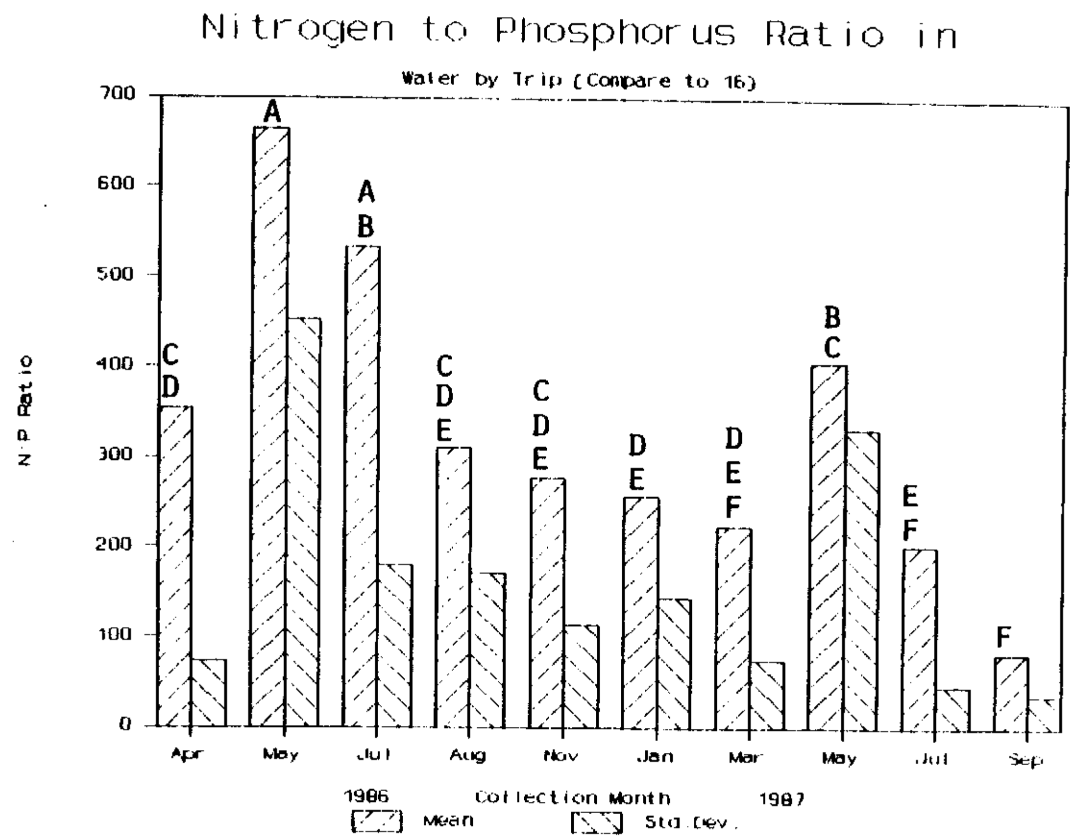
**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 56



251




**ANALYSIS OF VARIANCE RESULTS**

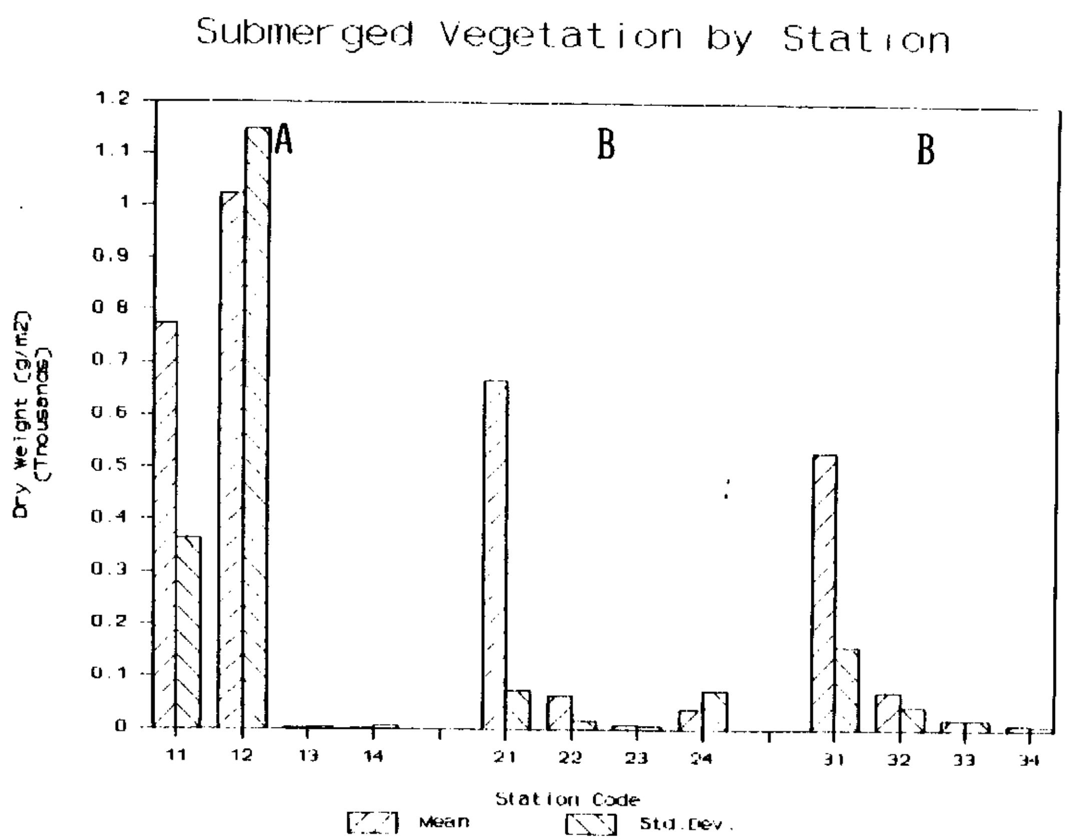
**NITROGEN TO PHOSPHORUS RATIO**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Date | .0001 |
| Loc X Date | .0029 |

Figure 57



252




**ANALYSIS OF VARIANCE RESULTS**

**SUBMERGED VEGETATION**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .0001 |
| System | .0107 |
| Loc X Syst | .0006 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | AB |
| 3 | B |
| 4 | B |

Figure 58

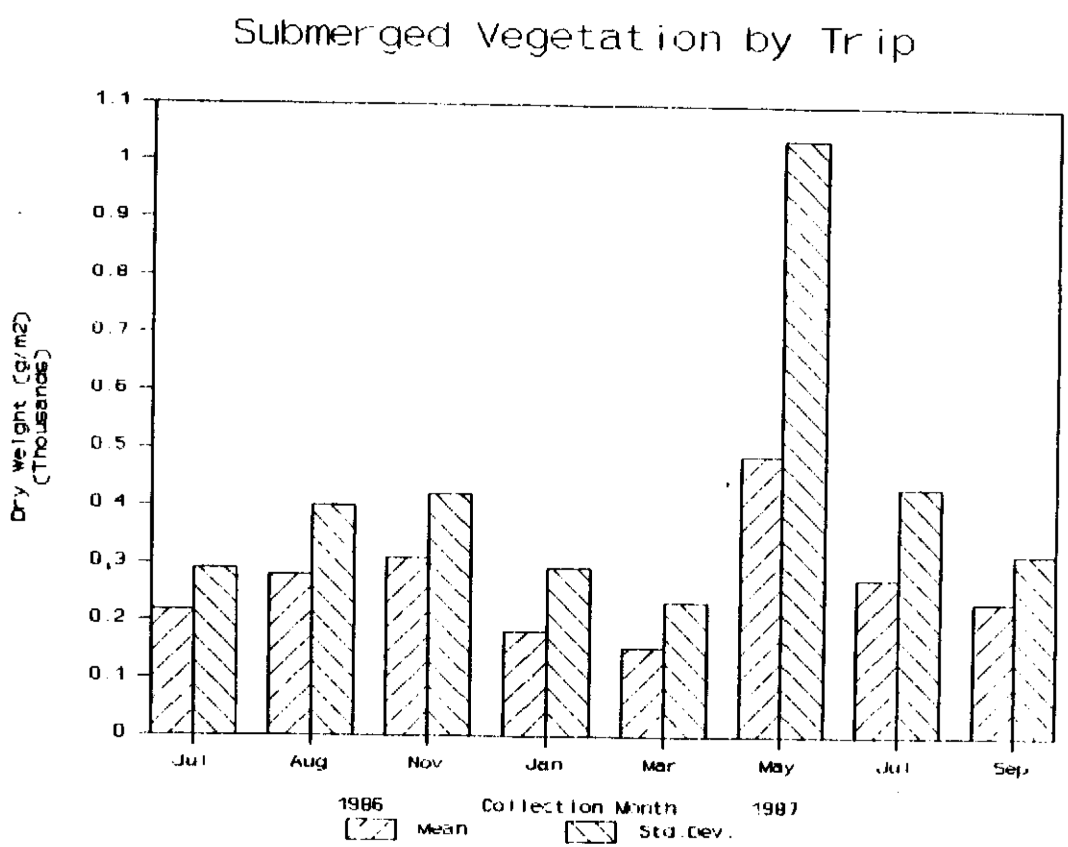
253

(> 99%) regression with location was obtained for station means (Appendix B, Observation 13). A slightly better regression was obtained when Lyngbya values were left out, leaving only macrophyte biomass in the regression (Appendix B, Observation 12). Considerable improvement in these regressions were obtained by taking the log of the mean total vegetation with or without Lyngbya (Appendix B, Observations 2 and 5).

Mean dry weight (over all trips) ranged over the extremes within the western system, from 2.1 g/m$^2$ at Taylor River Pond 3 (TRPD3) to 852 g/m$^2$ in Little Madeira Bay at the mouth of Taylor River (LMBTR). The highest single station estimate was 3821 g/m$^2$ at LMBTR in May 1987, when over 99% of the dry weight was attributable to the calcareous green alga Udotea. At the other extreme, no vegetation was found on 7 out of 8 visits to Taylor River Pond 3 (16.6 g/m$^2$ of Ruppia was found in November 1986). A film of microalgae was generally present at the sediment surface at all stations, and was especially noticeable at the upstream stations with little or no macrophytes. Measurement of this component of these ponds, however, requires a special sampling procedure not included in this study.

Seasonal variation in plant biomass was not significant either overall, or by location, though the highest means occurred in summer and the lowest in winter (Figure 59). Trip means ranged from a low of about 150 g/m$^2$ in March 1987 to a high of 480 g/m$^2$ in May 1987.

At each station, values varied considerably from trip to trip and from sample to sample, indicating either a patchy distribution of vegetation or reflecting temporal changes of the more rapidly growing and disappearing forms (especially macroalgae and collectable filamentous microalgae, i.e., Lyngbya). Higher standard deviations were generally associated with the




**ANALYSIS OF VARIANCE RESULTS**

**SUBMERGED VEGETATION**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0377 |
| Date | .6970 |
| Loc X Date | .0140 |

Figure 59



250

larger mean values of the outer stations. The least variable outer station was Northeast Trout Cove (NETCV), which varied only from 563 to 764 g/m$^2$ (and was always 97 to 100% Thalassia) during the period of consistent sampling methods (the eight trips from July 1986 through September 1987). At the mouth of Little Madeira Bay (LMBHS), dry weight declined from roughly 900 to 1400 g/m$^2$ during July, August, and November 1986 to 400 to 600 g/m$^2$ during January 1987 through the end of the field sampling (September 1987). At this station too, Thalassia remained the dominant vegetation throughout the sampling period.

The greatest variation of any of the stations occurred at Little Madeira Bay at the mouth of Taylor River, which was visually the most patchy station sampled. Patches of a variety of seagrasses and macroalgae were always present. Dry weight at this station in January and March 1987 was between 75 and 90 g/m$_2$, dominated by the shoalgrass Halodule, but by May 1987 was over 3800 g/m$^2$, of which 99.9% was Udotea. This probably reflects the patchiness of the station, however, rapid response to changing physical conditions cannot be eliminated as a possible explanation.

Upstream stations did not appear to be as spatially variable during each trip, but were temporally much more variable than the outer stations. The most variable upstream station was Snook Creek Pond 3 (SCPD3). This pond contained 347 g/m$^2$ of submerged vegetation (mostly Batophora and Chara) in April 1986 (and probably at least as much in March 1986, when it was observed but not sampled), but contained one-tenth that amount by the next time it was sampled in July 1986 and again in August 1986. During this period, the filamentous bluegreen alga, Lyngbya became increasingly prevalent and the two macroalgae declined. In August 1986, the vascular plant Halodule was also found. By November 1986, however, SCPD3 was covered by a thick mat of Lyngbya, which accounted for 233 g/m², and no other vegetation was found. In none of the five remaining trips did collectable vegetation at this pond ever exceed 1.2 g/m². It consisted of small quantities of Batophora, Chara, and the vascular plant Ruppia. Generally a mat of microalgae was present, but was not collected by our sampling methods.

Average Species Composition

As shown in Table 4, turtlegrass (Thalassia testudinum) greatly dominated the outermost western and central stations (93 and 99% of dry weight at LMBHS and NETCV respectively), while at the eastern outermost station (NELBS) the calcareous green algae Penicillus was similarly dominant (82%), with a lesser amount (13%) of Thalassia present. Seagrasses were the dominant vegetation at all of the next-to-outermost stations, but Thalassia was accompanied by near equal or greater amounts of the shoalgrass, Halodule wrightii. At these stations, Halodule comprised 30%, 78%, and 49% of the total dry weight for western, central, and eastern systems, while Thalassia accounted for 39%, 2%, and 32%, respectively. At the western next-to-outermost station (LMBTR), the calcareous green algae Udotea was also a significant contributor to total dry weight (average of 29%). A wide variety of minor species of vegetation accompanied the dominants at the two outer stations in each system. These included the brown macroalga Sargassum, the red macroalgae Laurencia and Polysiphonia, the calcareous green algae Acetabularia, Halimeda, Penicillus, and Udotea, and other green algae (Batophora, Chara, Cladophora, and Rhizoclonium), as well as the widgeongrass Ruppia. All three species of seagrass (Halodule, Ruppia, and Thalassia)

Table 4. Average species composition of submerged vegetation at all stations (July 86 through September 1987 field trips).

| | AVERAGE PERCENTAGE BY WEIGHT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Western Stations | | | | Central Stations | | | | Eastern Stations | | | |
| SPECIES | LMBHS | LMBTR | TRPD1 | TRPD3 | NETCV | LTLJB | NEJBY | SCPD3 | NELBS | NELSD | HCPD1 | NWHP2 |
| -- Algae -- | | | | | | | | | | | | |
| Lyngbya | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 29.88 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sargassum | 0.01 | 0.05 | 0.00 | 0.00 | 0.00 | 6.16 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 |
| Acetabularia | 2.65 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.00 | 0.00 |
| Batophora | 0.11 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 14.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Chara | 0.02 | 0.00 | 0.24 | 0.00 | 0.00 | 0.00 | 0.20 | 25.11 | 2.20 | 0.00 | 54.68 | 3.47 |
| Cladophora | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 |
| Halimeda | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Penicillus | 0.59 | 0.79 | 0.00 | 0.00 | 0.69 | 0.00 | 0.00 | 0.00 | 82.49 | 0.00 | 12.38 | 0.00 |
| Rhizoclonium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Udotea | 0.01 | 29.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Laurencia | 2.64 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Unid. Red Algae | 0.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polysiphonia | 0.00 | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Unidentified Algae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 |
| -- Seagrasses -- | | | | | | | | | | | | |
| Halodule | 0.08 | 29.76 | 16.81 | 0.00 | 0.10 | 78.30 | 49.46 | 16.18 | 1.37 | 49.00 | 2.63 | 72.55 |
| Ruppia | 0.01 | 0.00 | 20.45 | 12.50 | 0.03 | 5.84 | 46.20 | 14.46 | 0.09 | 11.58 | 7.05 | 23.96 |
| Rup/Hal | 0.00 | 0.98 | 12.50 | 0.00 | 0.00 | 8.05 | 4.13 | 0.00 | 1.09 | 7.48 | 4.54 | 0.00 |
| Thalassia | 93.01 | 38.53 | 0.00 | 0.00 | 99.13 | 1.65 | 0.04 | 0.00 | 12.64 | 31.73 | 0.00 | 0.00 |
| GRASS SUM | 93.10 | 69.28 | 49.76 | 12.50 | 99.25 | 93.84 | 99.82 | 30.64 | 15.19 | 99.78 | 14.22 | 96.51 |
| -- Unknown -- | | | | | | | | | | | | |
| ID Lost | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 6.23 | 0.00 |
| COLUMN SUM* | 100 | 100 | 50 | 12.5 | 100 | 100 | 100 | 100 | 100 | 100 | 81 | 100 |
| AVG BIOMASS ($g/m^2$) | 774 | 1023 | 1.95 | 2.08 | 667 | 64.1 | 8.66 | 38.1 | 530 | 70.6 | 19.1 | 10.4 |
| NUMBER OF SPECIES | 11 | 11 | 3 | 1 | 9 | 6 | 4 | 5 | 9 | 7 | 4 | 3 |

* Column Sum is less than 100% if a station had no vegetation during one or more trips. A sum of 25% means that vegetation occurred at the station on only 2 of the 8 visits between July 1986 and September 1987.



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were found during some trip to each of the two outer stations in each system. In addition, from west to east, a total of 8, 6, and 6 species of macroalgae were identified at the outermost stations during the course of the study, and 8, 3, and 4 species of macroalgae were found at the next to outermost stations.

At the two upstream stations in each system, not only was total dry weight much lower, but dominance shifted away from *Thalassia* and calcareous green algae to *Halodule*, *Ruppia*, and *Chara*, although the green alga *Batophora* and the filamentous bluegreen alga *Lyngbya* occurred briefly in great quantities at Snook Creek Pond 3, as described earlier. *Penicillus* was found only once (during the last trip, September 1987) at the first upstream eastern station (Highway Creek Pond 1), but accounted for so much weight compared to the total weight usually found there, that overall it accounted for 12% of the average species composition by dry weight. The number of species encountered at these upstream stations was also considerably lower than at the outer stations. For seagrasses and algae combined, the total numbers were 3, 4, and 4 species (west to east) for the first upstream station, and 1, 5, and 3 species (west to east) for the most upstream station in each system.

## Inorganic Ash Content of Plants

The ash content of vegetation is given in Table 5. For seagrasses average ash content ranged from 32 to 41% of total dry weight. Ash content of dead shoots and leaves was 4 to 6% higher than live shoots and leaves. Ash content of subterranean material (roots and rhizomes) was approximately the same as that of live shoots and leaves except in *Thalassia*, where ash

Table 5. Inorganic ash content of submerged vegetation expressed as a percentage of dry weight.

| SPECIES | | ASH CONTENT AS PERCENT OF DRY WEIGHT<br>-----Above Ground-----<br>Dead | Live | Total | Below Ground | Overall Average |
|---|---|---|---|---|---|---|
| -- Brown Algae -- | | | | | | |
| <u>Sargassum</u> | Mean | 41.4 | 31.7 | 32.3 | | 32.3 |
| | Std.Dev. | | 12.2 | 12.1 | | 12.1 |
| | No. Obs. | 1 | 15 | 16 | 0 | 16 |
| -- Green Algae -- | | | | | | |
| <u>Acetabularia</u> | Mean | 48.3 | 72.7 | 71.6 | 29.8 | 71.2 |
| | Std.Dev. | | 13.4 | 13.4 | | 14.2 |
| | No. Obs. | 1 | 40 | 40 | 1 | 40 |
| <u>Batophora</u> | Mean | | | 63.4 | | 63.4 |
| | Std.Dev. | | | 12.7 | | 12.7 |
| | No. Obs. | 0 | 0 | 38 | 0 | 38 |
| <u>Chara</u> | Mean | | 55.4 | 55.4 | 91.0 | 55.8 |
| | Std.Dev. | | 8.3 | 8.3 | | 9.3 |
| | No. Obs. | 0 | 36 | 36 | 1 | 36 |
| <u>Penicillus</u> | Mean | 89.5 | 72.7 | 72.7 | 92.1 | 85.3 |
| | Std.Dev. | | 7.9 | 8.1 | 2.8 | 6.3 |
| | No. Obs. | 1 | 82 | 82 | 63 | 80 |
| <u>Udotea</u> | Mean | 71.3 | 50.0 | 50.1 | 88.4 | 82.4 |
| | Std.Dev. | | 4.8 | 4.8 | 8.9 | 9.7 |
| | No. Obs. | 1 | 19 | 19 | 20 | 20 |
| -- Red Algae -- | | | | | | |
| <u>Laurencia</u> | Mean | | 51.1 | 51.1 | | 51.1 |
| | Std.Dev. | | 12.1 | 12.1 | | 12.1 |
| | No. Obs. | 0 | 37 | 37 | 0 | 37 |
| <u>Polysiphonia</u> | Mean | | 66.6 | 66.6 | | 66.6 |
| | Std.Dev. | | 11.5 | 11.5 | | 11.5 |
| | No. Obs. | 0 | 31 | 31 | 0 | 31 |
| -- Seagrasses -- | | | | | | |
| <u>Halodule</u> | Mean | 37.8 | 30.7 | 34.3 | 29.8 | 31.7 |
| | Std.Dev | 15.0 | 17.2 | 16.2 | 12.9 | 13.8 |
| | No. Obs. | 109 | 150 | 161 | 147 | 171 |
| <u>Ruppia</u> | Mean | 45.1 | 41.3 | 44.6 | 39.3 | 41.4 |
| | Std.Dev. | 15.8 | 23.5 | 21.0 | 19.3 | 21.1 |
| | No. Obs. | 17 | 33 | 34 | 32 | 38 |
| <u>Thalassia</u> | Mean | 40.4 | 30.1 | 37.0 | 35.9 | 36.8 |
| | Std.Dev. | 13.6 | 13.2 | 12.8 | 14.2 | 13.8 |
| | No. Obs | 120 | 123 | 147 | 125 | 162 |

content of roots and rhizomes averaged 6% higher.

Ash content of calcareous green algae was considerably higher than that of seagrasses: around 70% for the aerial portions and 90% for the below-ground holdfasts of Penicillus and Udotea (which generally contained marl sediment inseparable from the ball of holdfast filaments). The overall ash contents for these two calcareous algae as collected were 85% and 82% respectively. Overall ash contents of other macroalgae were generally in the range of 51% to 67%. Ash content of Sargassum was very low at 32%.

Percentage Below Ground

The percentage of the total dry weight that is below ground is given in Table 6 for those major species that have a significant below-ground component (seagrasses and the principal algae with holdfasts, Penicillus and Udotea). For the seagrasses, 60% to 75% of the total dry weight was below-ground. For Udotea, 87% was below-ground. The percentage below-ground for Thalassia was much lower than average at the eastern outermost station (Northeast Little Blackwater Sound) and higher than average at the outermost stations of the central and western systems (Northeast Trout Cove and Little Madeira Bay Hydrostation). A similar pattern occurred for Halodule between the outermost eastern and western stations.

Variation in the amount of dry weight below-ground was greatest among samples of Ruppia. This plant exhibited two growth forms. When beginning to flower, it was found with considerable branching apical growth of leaves and stems, longer than required to reach the surface of the water and bending over just below the surface. This growth form occurred in Northeast Joe Bay during one trip. Often, however, Ruppia consisted of sparse fragile leaves

Table 6. Belowground biomass of submerged vegetation expressed as a percentage of total biomass.

| SPECIES | Code | Location | PERCENT OF TOTAL DRY WEIGHT | | |
|---|---|---|---|---|---|
| | | | Mean | Std.Dev. | No. Samples |
| -- Green Algae -- | | | | | |
| Penicillus | 21 | NETCV | 62.7 | 23.4 | 10 |
| | 12 | LMBTR | 69.7 | 21.8 | 7 |
| | 31 | NELBS | 72.1 | 12.8 | 36 |
| | 33 | HCPD1 | 74.6 | | 1 |
| | 11 | LMBHS | 76.2 | 2.6 | 3 |
| | | Overall | 70.4 | 16.5 | 57 |
| Udotea | 11 | LMBHS | 42.4 | | 1 |
| | 12 | LMBTR | 90.3 | 6.7 | 12 |
| | | Overall | 86.6 | 14.3 | 13 |
| -- Seagrasses -- | | | | | |
| Halodule | 33 | HCPD1 | 40.3 | 0.0 | 1 |
| | 31 | NELBS | 61.0 | 28.0 | 7 |
| | 12 | LMBTR | 67.7 | 22.7 | 30 |
| | 32 | NELSD | 70.8 | 23.1 | 28 |
| | 22 | LTLJB | 71.8 | 17.3 | 28 |
| | 23 | NEJBY | 73.0 | 10.4 | 12 |
| | 34 | NWHP2 | 82.5 | 19.0 | 11 |
| | 11 | LMBHS | 85.8 | 10.7 | 3 |
| | 24 | SCPD3 | 89.5 | 0.0 | 1 |
| | 21 | NETCV | 92.4 | 3.3 | 2 |
| | | Overall | 71.6 | 21.2 | 123 |
| Ruppia | 23 | NEJBY | 28.0 | 23.7 | 4 |
| | 24 | SCPD3 | 62.4 | | 1 |
| | 34 | NWHP2 | 66.1 | 25.4 | 8 |
| | 33 | HCPD1 | 68.2 | 7.3 | 4 |
| | 32 | NELSD | 83.1 | | 1 |
| | 21 | NETCV | 95.8 | | 1 |
| | | Overall | 60.8 | 27.2 | 19 |
| Thalassia | 31 | NELBS | 53.2 | 22.5 | 13 |
| | 11 | LMBTR | 65.9 | 15.4 | 13 |
| | 32 | NELSD | 76.5 | 2.9 | 4 |
| | 21 | NETCV | 81.0 | 12.9 | 35 |
| | 11 | LMBHS | 81.7 | 7.8 | 34 |
| | 30 | NEBWS | 87.2 | | 1 |
| | | Overall | 75.5 | 16.7 | 100 |

just barely visible along the bottom sediments. The other seagrasses do not have the surface-seeking branched growth form. Variation in leaf length above the bottom, however, was noticeable during our sampling. Although quantitative measurements of leaf length were not made, leaves of Thalassia and Halodule were usually very short at the outermost western and central stations (LMBHS and NETCV), but longer at the two outer stations of the eastern system (NELBS and NELSD), and the next to outermost station of the western system (LMBTR).

## Benthic Fauna

Of the 22,508 sorted and cataloged animals collected in 1,641 placements of sampling devices between August 1986 and September 1987, 89% were less than 1.0 cm in total length, 10% were between 1 and 2.5 cm, and less than 1% were greater than 2.5 cm. Annelids (mostly polychaetes), arthropods (almost exclusively amphipod, isopod, and decapod crustaceans), and mollusks (bivalves and snails) accounted for 92% of the individuals (44%, 29%, and 19%, respectively).

The four devices used for collecting benthic epifauna and infauna (epifauna nets, shallow cores, deep cores, and domes) differed in the portion of the benthic community sampled, but with some overlap (Figure 60). Sixty-five percent of the total number of individuals sampled were collected in the 209 placements of the epifauna nets, which represent only 13% of the total number of device placements. In these samples, 94% of the individuals were less than 1.0 cm in total length. Another 30% was collected in the 844 small cores, in which 73% were less than 1.0 cm. Only 3% of the individuals were collected in the 168 dome samples, which contain only those epifauna

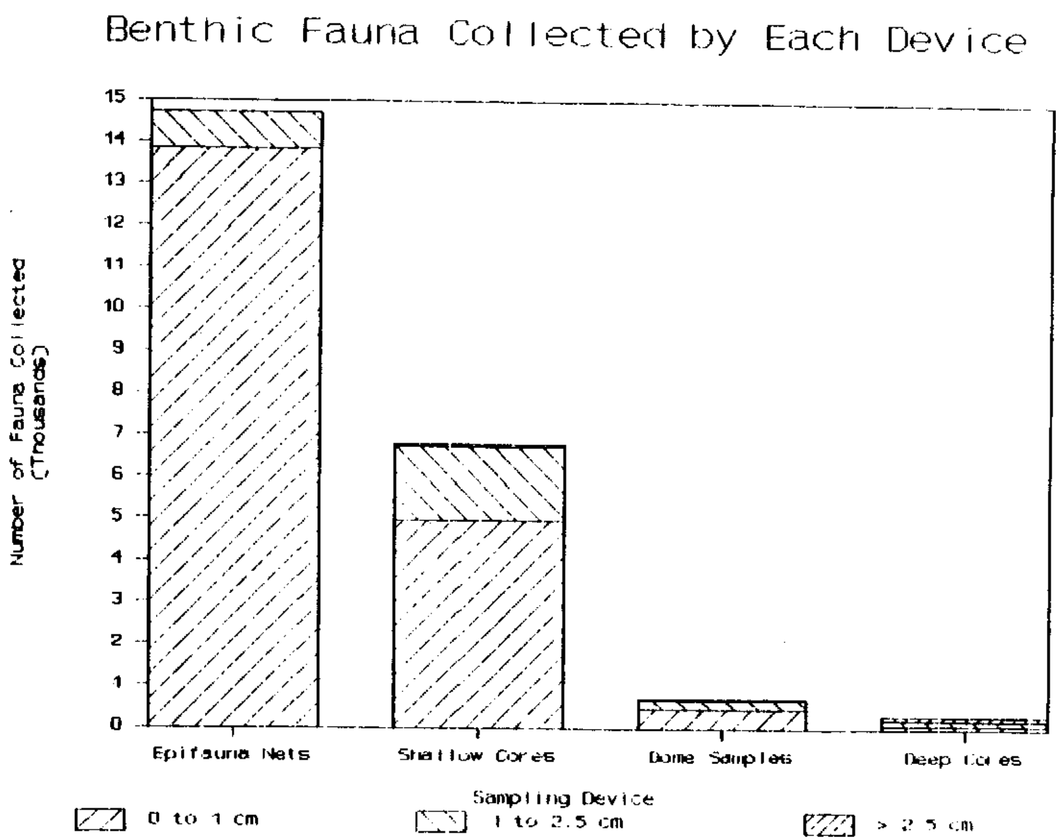


Figure 60



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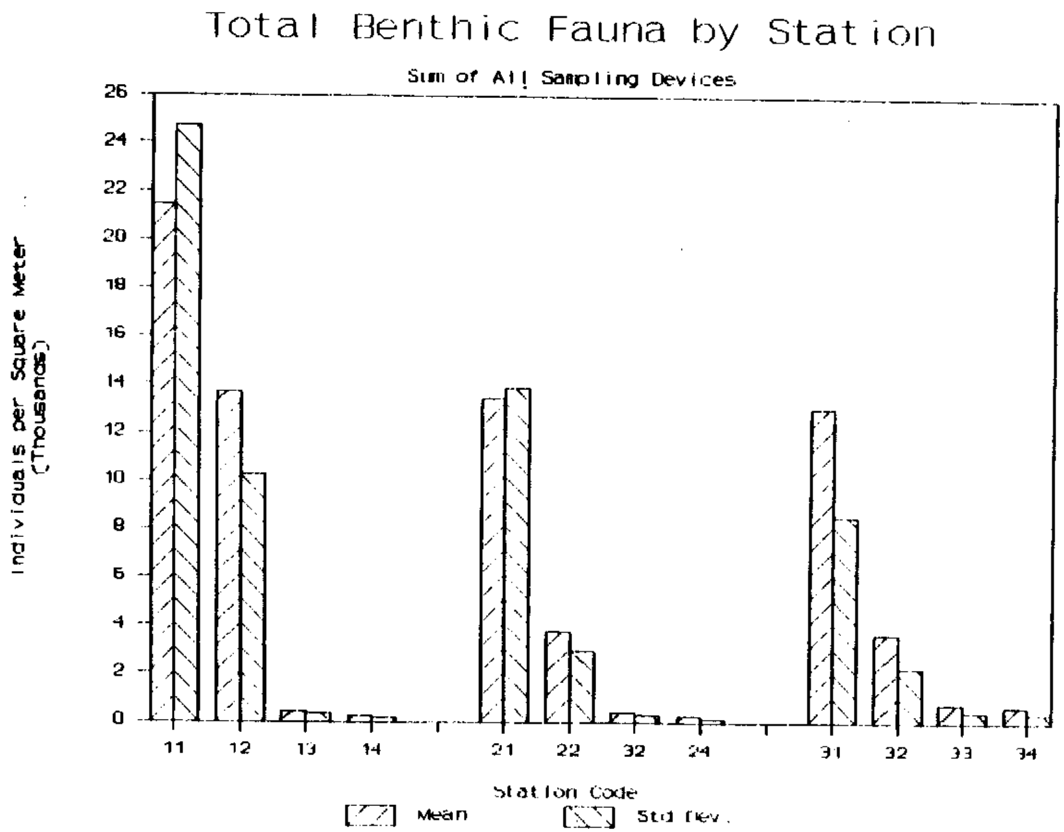
that did not escape during the removal of grasses from domes. Ninety-two percent of these dome epifauna were less than 1.0 cm in length. The remaining 1 to 2% of the individuals were collected in the 420 deep cores (sieved through a 5 mm mesh screen), but 70% of these individuals were greater than 1 cm in total length.

Density of Benthic Fauna

The overall average density of individuals collected by all sampling devices at all stations and trips was 5980 per $m^2$, of which 80% were from the epifauna nets and 19% were from the shallow cores. The other two devices (deep cores and domes) together accounted for less than 1% of the density (38.6 and 16.0 individuals per $m^2$, respectively). Overall density varied considerably from station to station in a consistent and dramatic pattern from upstream to outer stations (Figure 61). Station means and standard deviations, when regressed against location, significantly (> 99%) declined upstream (Appendix B, Observations 3 and 10). The most significant regression, however, was with the log of the mean values (Appendix B, Observation 1).

The outermost stations averaged 16,980 per $m^2$, but average densities declined precipitously at the more upstream stations (7056, 497, and 367 individuals per $m^2$, respectively). Furthermore, although fauna collected in all devices declined, the proportion of the total collected in the epifauna nets declined from 87% to 71, 32, and 16%, while the proportion from the shallow cores increased from 12% to 27%, 66%, and 80% from outer to upstream stations (Figure 62).




**ANALYSIS OF VARIANCE RESULTS**

**TOTAL BENTHIC FAUNA**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0012 |
| Location | .0001 |
| System | .2683 |
| Loc X Syst | .7961 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | A |
| 3 | C |
| 4 | C |

Figure 61



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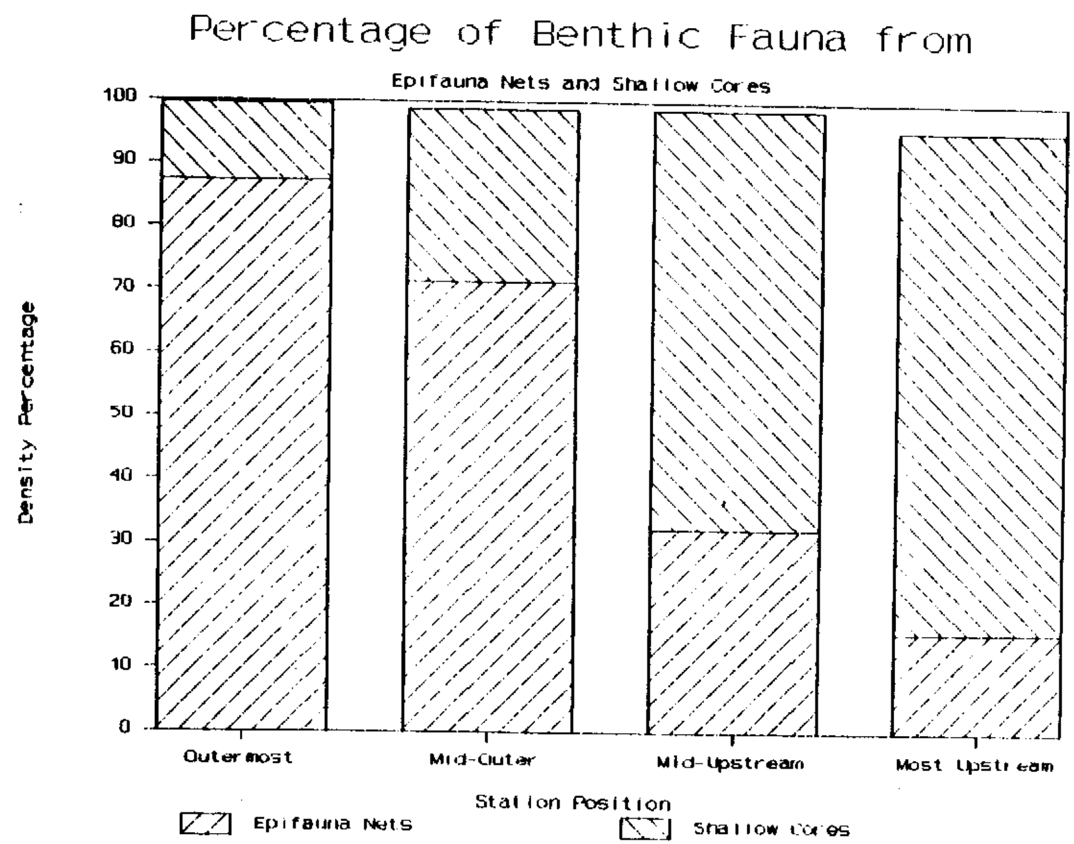

Percentage of Benthic Fauna from
Epifauna Nets and Shallow Cores
Density Percentage
100
90
80
70
60
50
40
30
20
10
0
Outermost
Mid-Outer
Mid-Upstream
Most Upstream
Station Position
Epifauna Nets
Shallow Cores

Figure 62

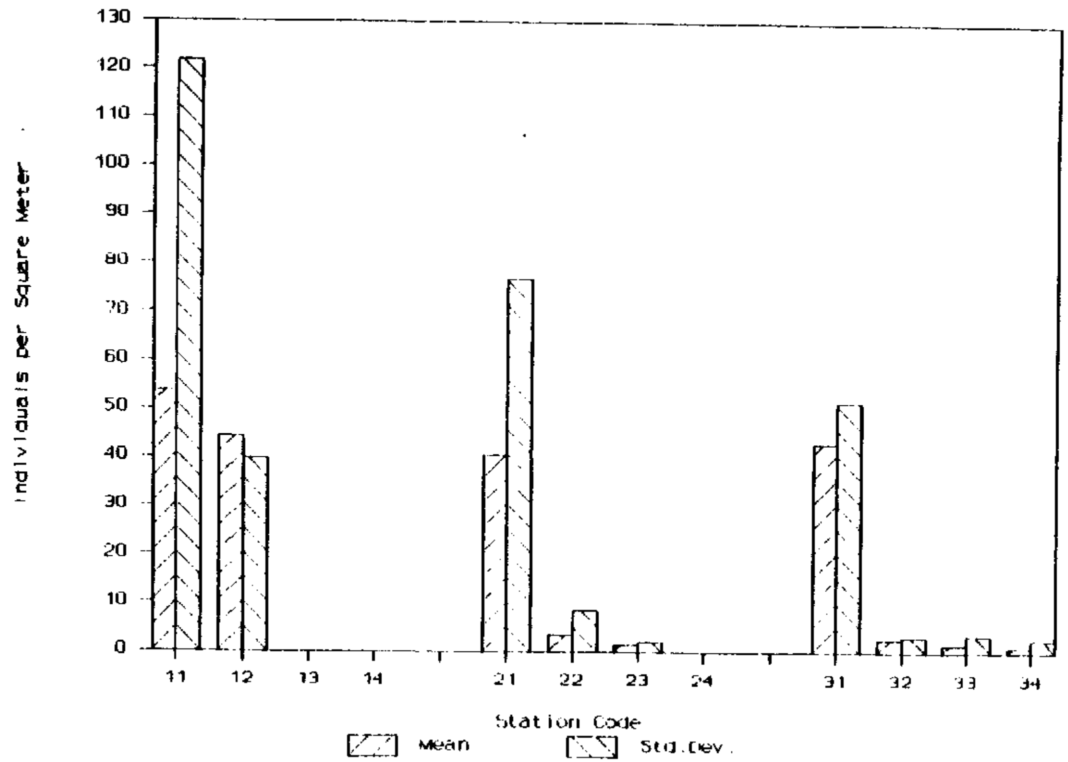
Epifauna collected in domes, although accounting for only a tiny portion of the total, followed a similar pattern of precipitous decline at upstream stations (Figure 63). The few large infauna collected in the deep cores also followed this pattern. The upstream two stations averaged about one-fifth of the numbers of large infauna found at the outer two stations (Figure 64).

Collections of fauna from individual trips ranged from zero collected using any device at either Taylor River Pond 1 or Pond 3 (TRPD1 and TRPD3) in May 1987 to 75,034 per $m^2$ near the mouth of Little Madeira Bay (LMBHS) in September 1987. This large estimate of fauna is 1.72 times higher than the next highest total density found -- at Northeast Trout Cove (NETCV) in July 1987 (43,416 per $m^2$). It is attributable to the over 2200 polychaetes found entangled in a piece of decomposing sponge collected in one of the three epifauna net samples taken at LMBHS on this trip. Even without this value, however, the overall upstream to outer station pattern is the same.

For all other devices, the peak average density (over all stations) occurred in July 1987. If the one epifauna net sample is excluded from the September 1987 mean, then the peak density for epifauna net samples would also be in July 1987. Despite this, the apparent differences from month to month are not statistically significant, either overall (Figure 65), or when analyzed separately by location. Average density (over all stations) ranged from 2,035 per $m^2$ in January 1987 to 11,126 per $m^2$ in September 1987 (or 9,072 per $m^2$ in July 1987).

The overall averages for the two outermost stations of the western system (LMBHS and LMBTR) are higher than their counterparts in the central and eastern systems (NETCV and LTLJB in central; NELBS and NELSD in eastern).

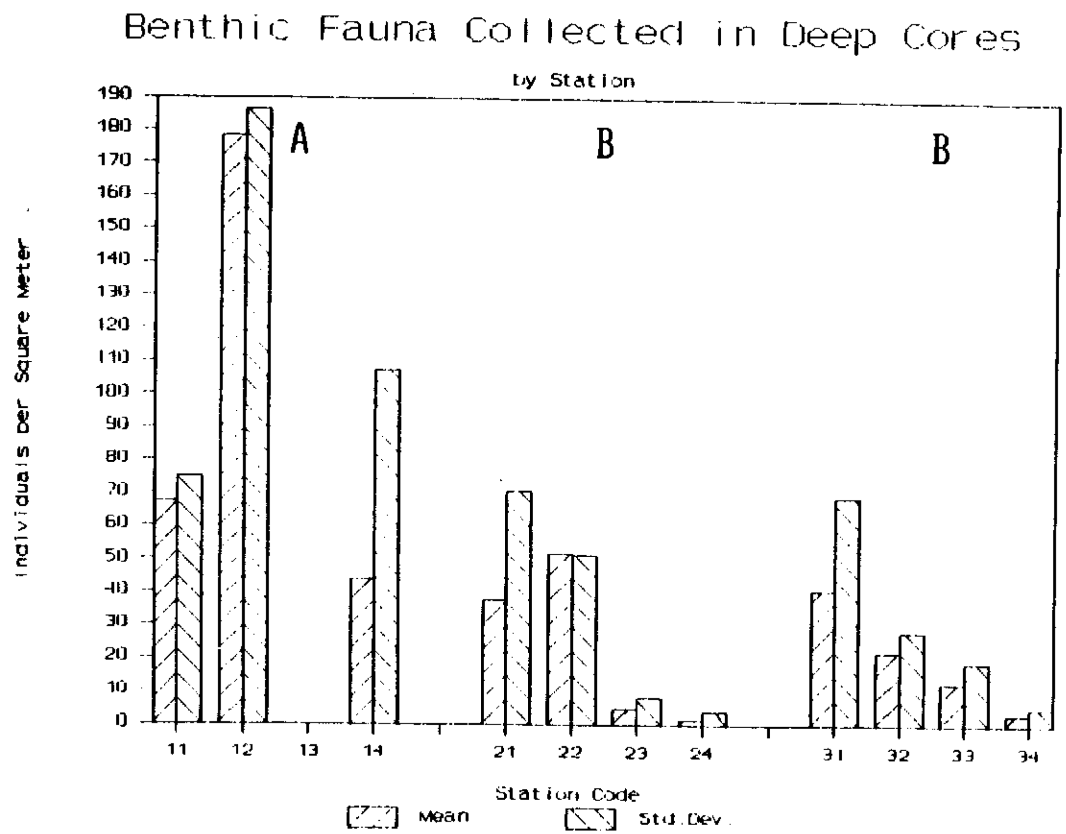
Benthic Fauna Collected in Domes




| ANALYSIS OF VARIANCE RESULTS | |
|---|---|
| BENTHIC FAUNA FROM DOMES | |
| Fixed Effect | Significant Probability |
| Model | .1974 |
| Location | .0121 |
| System | .5340 |
| Loc X Syst | .8893 |

| WALLER-DUNCAN GROUPING | |
|---|---|
| Location | Group |
| 1 | A |
| 2 | AB |
| 3 | B |
| 4 | B |

Figure 63




**ANALYSIS OF VARIANCE RESULTS**

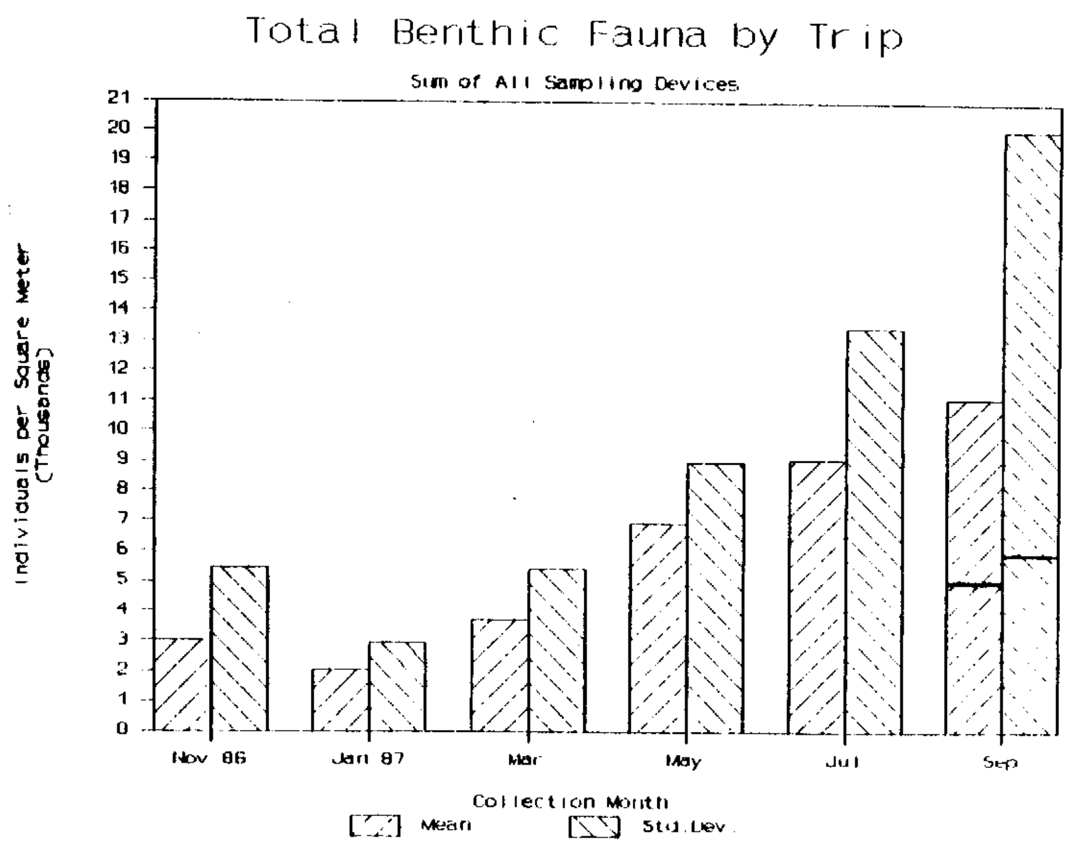
**BENTHIC FAUNA IN DEEP CORES**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0061 |
| Location | .0094 |
| System | .0273 |
| Loc X Syst | .1613 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | AB |
| 2 | A |
| 3 | B |
| 4 | B |

Figure 64




**ANALYSIS OF VARIANCE RESULTS**

**TOTAL BENTHIC FAUNA**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0106 |
| Date | .1978 |
| Loc X Date | .0083 |

Figure 65

Because of the dominance of the outer stations in the overall means for each system, the western stations appear to have greater faunal densities. Faunal densities in the upstream stations, however, are much lower in the western system, increasing two-fold in the eastern system (the central system's upstream stations are intermediate in density). Without the very large September 1987 epifauna net value at LMBHS, faunal density in the outermost stations would also increase from west to east. In that case, however, the only station not following this pattern would be that in Little Madeira Bay at the mouth of Taylor River (LMBTR).

## Effect of Screen Size on Shallow Core Density

When a 1 mm screen was used in 74 randomly chosen (out of 720) shallow core samples (rather than the routinely used 2 mm screen), an average of three times more animals were found in the 1 to 2 mm fraction of material in than in the fraction greater than 2 mm. Sample variability was very high (standard deviation greater than the mean), however, and no consistent temporal or spatial patterns were apparent. If this small sample is representative of the average increase that would be found if a 1 mm screen had been used throughout, the shallow core density would perhaps increase from 1156 to approximately 4400 individuals per square meter and total density from 5980 to 9320 per square meter. Shallow cores would then account for 47% of the density and epifauna nets 51%.

## Overall Composition of Benthic Fauna by Class

A total of ten phyla were collected with the four sampling devices. In all but two (chaetognaths and sipunculids), animals were identified to class or to finer taxonomic levels. Animals from 14 taxonomic classes were identified (Table 7). About 90% of all individuals collected were in one of the following three classes: polychaete annelids, malacostracan crustaceans, and bivalve gastropods. Each of the four sampling devices differed somewhat in the portion of the community of fauna sampled, and some of these differences are reflected in the percentage of each type of fauna collected in each of the three categories of size. In the less than one cm category, polychaetes dominated the epifauna net samples (55%), followed by malacostracans (27%), bivalves (13%), gastropods (2%), and the rest (3%). Malacostracans, however, were most prevalent in the shallow cores (36%), followed by polychaetes (25%), bivalves (25%), and oligochaetes (4%). Deep cores produced few of the smallest category of fauna (< 1.0 cm), but of these, 96% were bivalves. In the dome samples, 63% of the smallest category were malacostracans and 33% were bivalves. The malacostracan crustaceans were primarily peracaridians (mainly amphipods, isopods, and tanaids). Decapod shrimps and crabs were rare, accounting for only about 3% of the animals in the epifauna net samples, 1% of those in the shallow cores, 2% of those in the deep cores, and less than 1% of those in the dome samples.

Abundance and Relative Dominance of Major Phyla

The abundance and dominance of the major phyla (annelids, arthropods, and mollusks) varied with time and with station, though in no trip or station was their collective average dominance less than 88% of all fauna. The overall collective average dominance of these three phyla was 95%. The only station at which less than 94% of the total fauna are represented by these

Table 7. Comparison of devices used to sample benthic fauna.

| CLASS or PHYLUM | PERCENTAGE OF TOTAL NUMBER IN EACH SIZE (cm) CATEGORY | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -- Epifauna Net -- | | | -- Shallow Core -- | | | --- Deep Core ---- | | | -- Dome Sampler -- | | |
| Size: | 0.1-1 | 1-2.5 | >2.5 | 0.2-1 | 1-2.5 | >2.5 | 0.1-1 | 1-2.5 | >2.5 | 0.1-1 | 1-2.5 | >2.5 |
| -- Invertebrates -- | | | | | | | | | | | | |
| Anthozoa | 1.28 | 0.70 | 0.00 | 0.56 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 | 0.00 | 0.00 | 0.00 |
| Hydrozoa | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gastropoda | 2.09 | 2.06 | 0.00 | 1.66 | 1.81 | 1.47 | 0.00 | 2.65 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bivalvia | 12.98 | 23.56 | 0.00 | 24.84 | 16.76 | 11.79 | 0.00 | 2.65 | 0.00 | 0.89 | 5.58 | 0.00 |
| Polychaeta | 54.95 | 11.86 | 34.62 | 25.21 | 52.24 | 64.48 | 95.56 | 58.41 | 6.06 | 33.48 | 57.08 | 14.29 |
| Oligochaeta/Polych. | 0.12 | 0.82 | 0.00 | 3.78 | 4.36 | 2.95 | 2.22 | 26.55 | 56.57 | 2.23 | 11.16 | 71.43 |
| Echiura | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.96 | 19.19 | 0.00 | 1.72 | 3.57 |
| Pycnogonida | 0.24 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 2.02 | 0.00 | 0.00 | 0.00 |
| Insecta | 0.05 | 0.65 | 0.00 | 0.71 | 1.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Malacostraca | 27.22 | 51.77 | 0.00 | 36.41 | 7.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Holothuroidea | 0.05 | 6.26 | 0.00 | 0.10 | 0.44 | 0.00 | 2.22 | 3.54 | 3.03 | 63.39 | 23.61 | 3.57 |
| Echinoidea/Ophiur. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | 0.00 | 0.88 | 0.00 | 0.00 | 0.00 | 3.57 |
| -- Vertebrates -- | | | | | | | | | | | | |
| Osteichthys | 0.14 | 1.64 | 42.31 | 0.10 | 1.09 | 4.42 | 0.00 | 0.00 | 2.02 | 0.00 | 0.00 | 0.00 |
| -- Misc. Phyla -- | | | | | | | | | | | | |
| Nemerteans | 0.27 | 0.56 | 0.00 | 2.13 | 2.57 | 1.47 | 0.00 | 0.00 | 10.10 | 0.00 | 0.00 | 3.57 |
| Chaetognatha | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sipuncula | 0.21 | 0.12 | 0.00 | 1.87 | 8.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other* | 0.16 | 0.00 | 23.08 | 2.55 | 3.27 | 13.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 | 0.00 |
| TOTAL | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

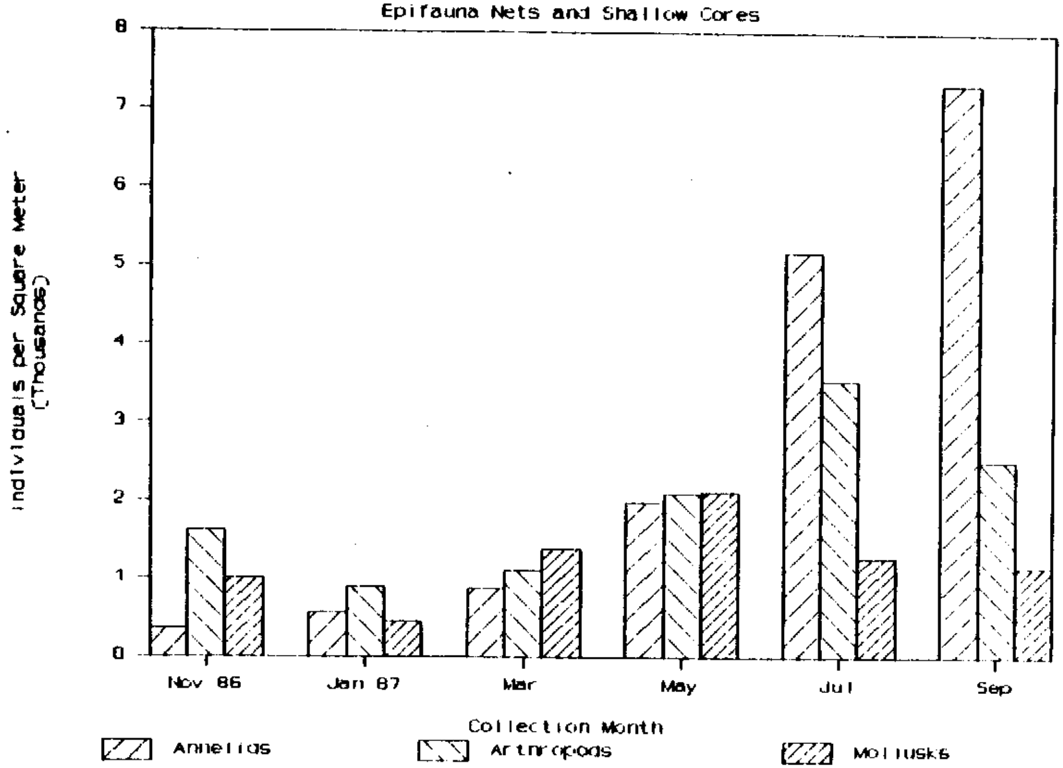
* Other includes invertebrates that could not be identified after preservation (e.g. colonial tunicates, sponges, bryozoans).

three phyla is the eastern outermost station (Northeast Little Blackwater Sound).

During the sampling period from November 1986 to September 1987, each of the three phyla reached peaks in successive trips, though no significant effect of date was detected by ANOVA (Figure 66). Mollusks peaked first in May 1987 at 2122 per $m^2$, followed by arthropods in July 1987 at 3533 per $m^2$, and then annelids in September 1987 at 7336 per $m^2$. The relative dominance of each group (as percentage of total fauna), however, followed a slightly different seasonal pattern (Figure 67). Annelids were relatively non-dominant in the first trip reported (11% in November 1986), but built to a peak of dominance by the last trip (66% in September 1987). Arthropod dominance mirrored this pattern: it was greatest on the first trip (51%), but steadily declined to 23% by the last trip. Mollusk dominance peaked in March 1987 (38%), but declined sharply on subsequent trips to a September low of 10% of the total fauna. The precipitous decline in total fauna at the upstream stations is not accompanied by similarly dramatic patterns of change in relative dominance from downstream to upstream (Figure 68). From west to east, however, some shifts in dominance are apparent. Annelids dominate the western system stations, but mollusks are relatively non-dominant there. Arthropods are relatively dominant at the central stations, though compared to the western stations, less of an imbalance occurs among the three phyla at most of the central stations. Fauna are most evenly distributed among the three dominant phyla in the eastern system.

# Sum of Benthic Fauna from

Epifauna Nets and Shallow Cores




**ANALYSIS OF VARIANCE RESULTS**

**ANNELIDS, ARTHROPODS, MOLLUSKS**

| Fixed Effect | Significant Probability | | |
|---|---|---|---|
| | Ann. | Arthr. | Moll. |
| Model | .3349 | .0494 | .2085 |
| Date | .3857 | .4438 | .6691 |
| Loc X Date | .3236 | .0307 | .1313 |

Figure 66

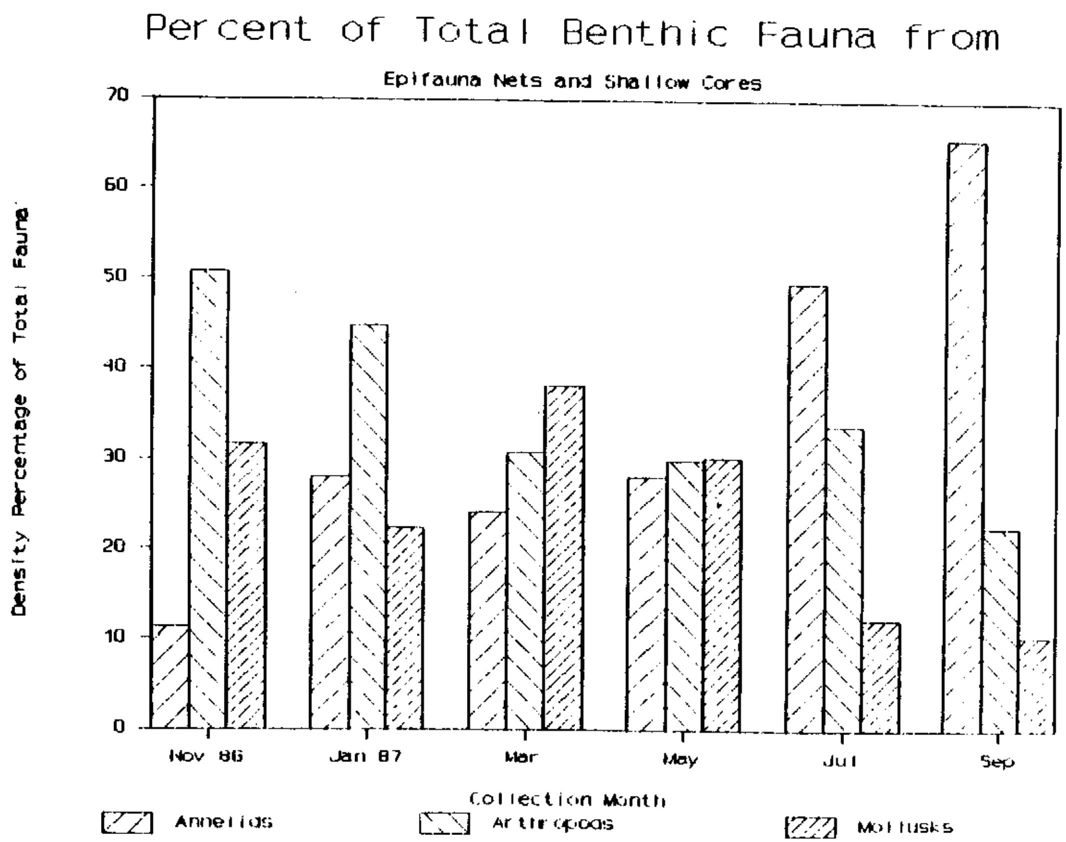
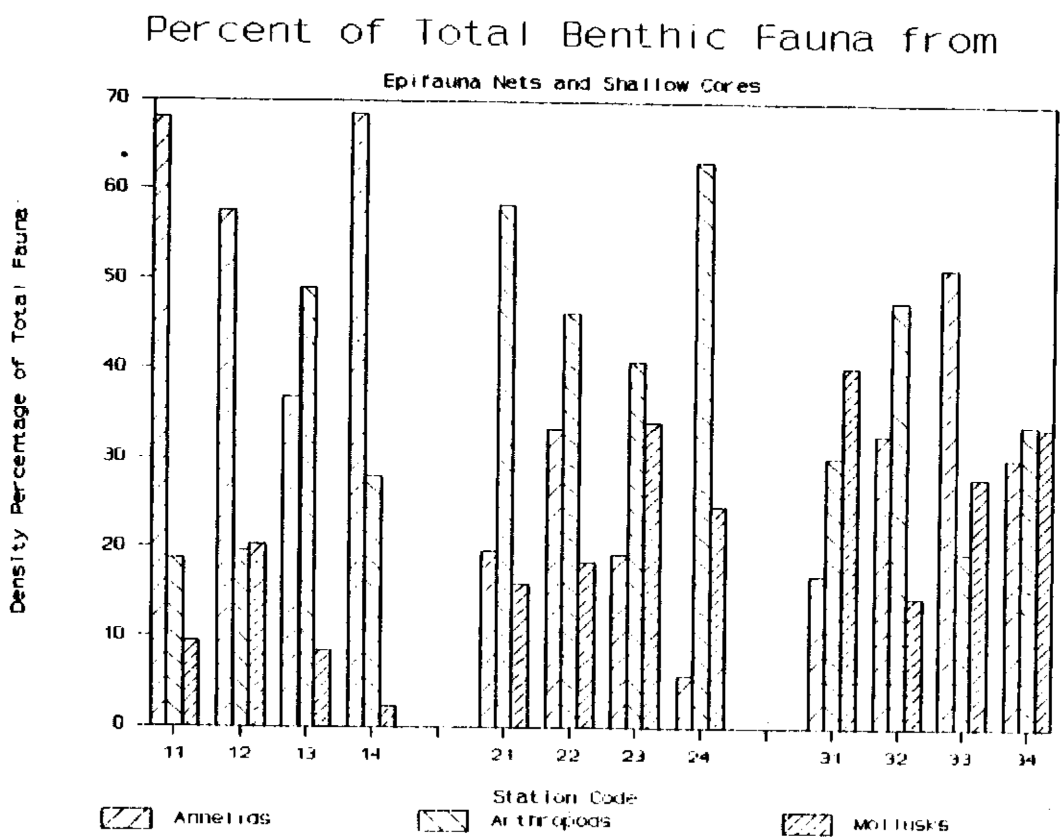

Percent of Total Benthic Fauna from
Epifauna Nets and Shallow Cores
Density Percentage of Total Fauna
0
10
20
30
40
50
60
70
Nov 86
Jan 87
Mar
May
Jul
Sep
Collection Month
Annelids
Arthropods
Mollusks

Figure 67




**ANALYSIS OF VARIANCE RESULTS**

**ANNELIDS, ARTHROPODS, MOLLUSKS**

| Fixed Effect | Significant Probability Ann. | Arth. | Moll. |
|---|---|---|---|
| Model | .1804 | .0040 | .0001 |
| Location | .1047 | .0001 | .0001 |
| System | .1179 | .7982 | .2142 |
| Loc X Sys | .5528 | .7615 | .0073 |

**WALLER-DUNCAN GROUPING**

| Location | Ann. | Arth. | Moll. |
|---|---|---|---|
| 1 | - | A | A |
| 2 | - | B | B |
| 3 | - | C | C |
| 4 | - | C | C |

Figure 68

## Oxygen Metabolism

### Open-water Oxygen Change

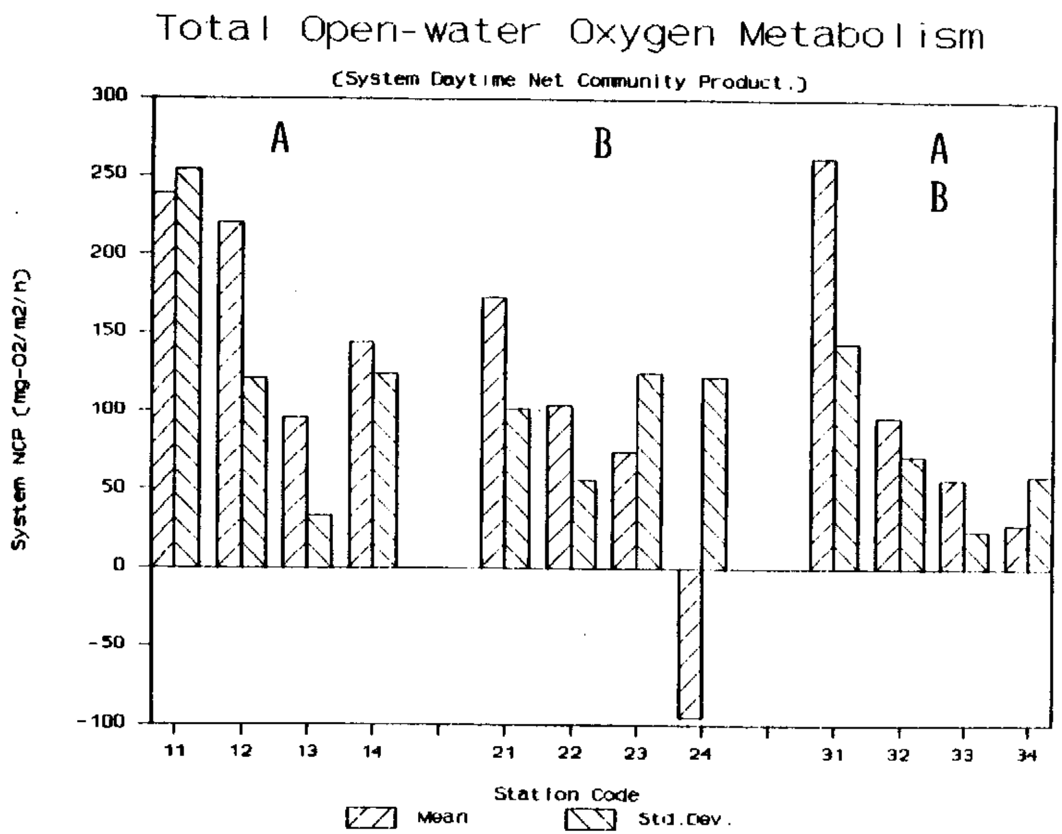
Daytime oxygen change in open water provided an estimate of whole-system (plankton and benthos) net community production. The overall open water rate of oxygen change averaged 117 mg-$O_2/m^2/h$ (of which 62% is attributable to the bottom half of the water column). Net community production consistently declined from outer to upstream stations (Figure 69; see also Appendix B, Observation 9). The average of the six most upstream stations (2 in each of 3 systems) was 50.7 mg-$O_2/m^2/h$, 28% of the outer station average. Individual station averages ranged from -95.2 mg-$O_2/m^2/h$ at Snook Creek Pond 3 (SCPD3) to 263 mg-$O_2/m^2/h$ at Northeast Little Blackwater Sound (NELBS). Temporal variation in net community production was great (Figure 70). Average net community production per trip (over all stations) was high in August 1986 (144 mg-$O_2/m^2/h$), but declined to a very low rate in March 1987 (12.8 mg-$O_2/m^2/h$), when five of the 12 stations exhibited negative net community production (positive net respiration). Net community production rose to a peak value of 172 mg-$O_2/m^2/h$ during July 1987. Individual estimates for stations ranged from -276 mg-$O_2/m^2/h$ at Snook Creek Pond 3 (SCPD3) in November 1986 to 835 mg-$O_2/m^2/h$ at Little Madeira Bay Hydrostation in August 1986.

### Light and Dark Bottle Oxygen Change

The difference in oxygen change in light and dark bottles is an estimate of planktonic gross primary production. The overall average for all stations and dates was 25.1 mg-$O_2/m^2/h$. The upstream six stations averaged 34 mg-$O_2/m^2/h$, 2.1 times higher than the outer stations, however,



28




**ANALYSIS OF VARIANCE RESULTS**

**TOTAL OPEN-WATER OXYGEN METAB.**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0001 |
| Location | .0001 |
| System | .0075 |
| Loc X Syst | .2600 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | B |
| 3 | BC |
| 4 | C |

Figure 69



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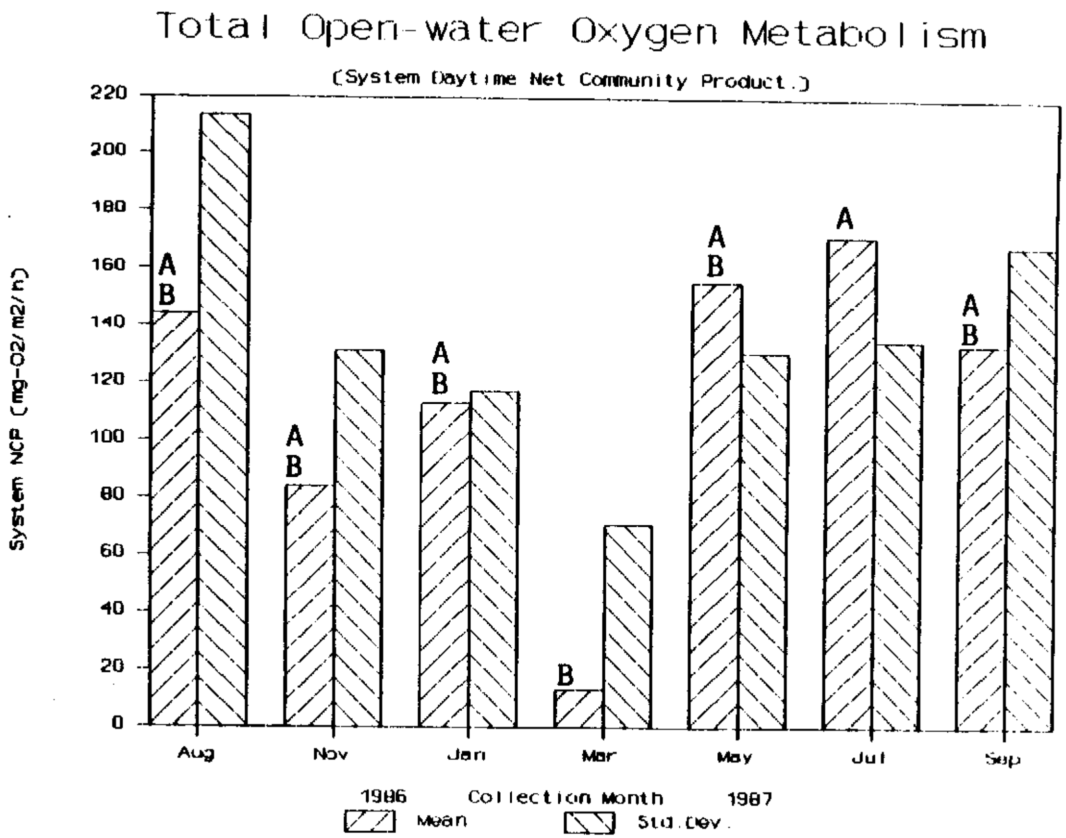



**ANALYSIS OF VARIANCE RESULTS**

**TOTAL OPEN WATER OXYGEN METAB.**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0485 |
| Date | .1124 |
| Loc X Date | .0680 |

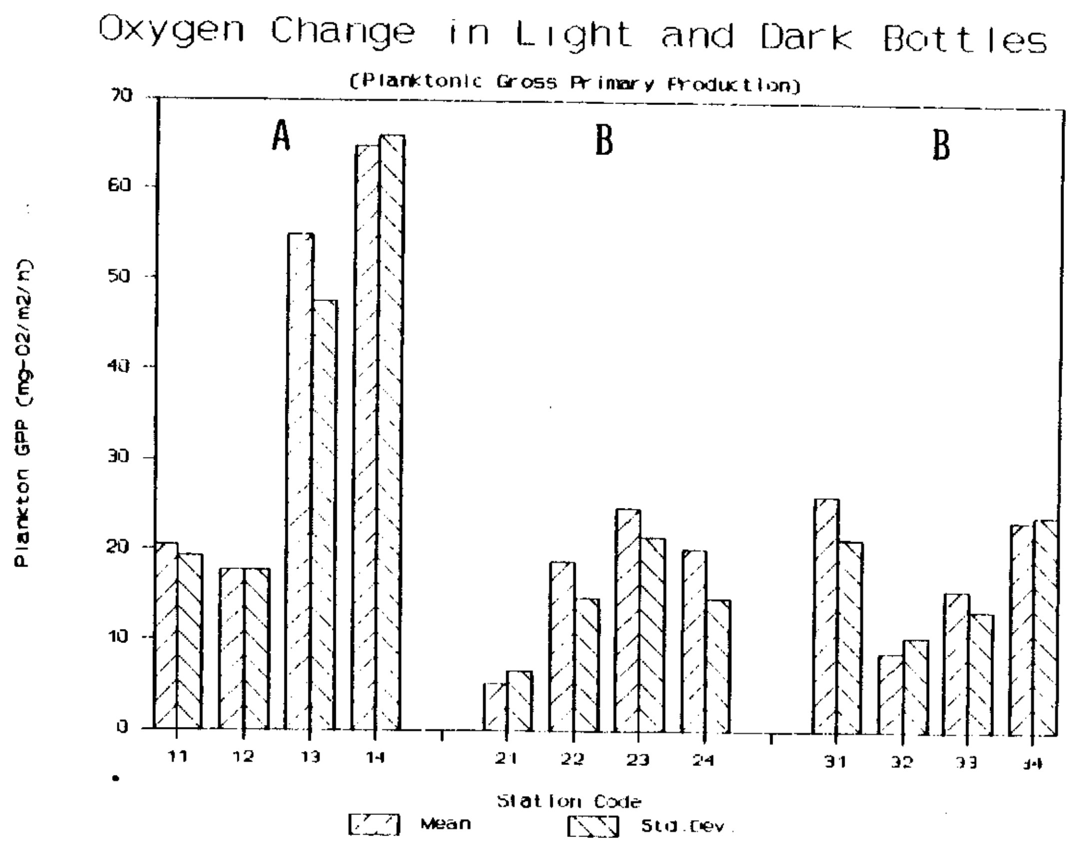
Figure 70

the pattern from outer to upstream stations was not as consistent as it was for total metabolism (Figure 71). The upstream stations at Taylor River were highest. Station means (over all trips) ranged from 5.18 mg-$O_2/m^2/h$ at Northeast Trout Cove (NETCV) to 64.9 mg-$O_2/m^2/h$ at Taylor River Pond 3 (TRPD3). Seasonal variation was not significant (Figure 72). Values of zero occurred in 14 out of 84 station-date observations. These were most common in May and July 1987, and were more common at outer stations. The highest value recorded was 200 mg-$O_2/m^2/h$ at Taylor River Pond 3 in July 1987.

Oxygen Uptake in Opaque Domes

Oxygen uptake in opaque domes provided an estimate of whole-system (plankton and benthos) community respiration. The overall mean oxygen uptake in domes was 32.3 mg-$O_2/m^2/h$, with relatively little variation from station to station compared to the previously reported measures of metabolism (Figure 73. Nevertheless, outer stations of the eastern system averaged 48 mg-$O_2/m^2/h$, 2.7 times higher than the upstream stations of this system (Highway Creek). Overall, upstream stations averaged 26.7 mg-$O_2/m^2/h$, and outer stations averaged 37.9 mg-$O_2/m^2/h$. Station averages (over all trips) ranged from 13.5 mg-$O_2/m^2/h$ at Northwest Highway Creek Pond 2 (NWHP2) to 58.3 mg-$O_2/m^2/h$ at Northeast Long Sound (NELSD).

As indicated in Figure 74, trip means (over all stations) were highest in August 1986 (68.1 mg-$O_2/m^2/h$), declined to a sub-minimum in March 1987 (21.2 mg-$O_2/m^2/h$), increased slightly in May 1987, but dropped to a minimum in July 1988 (18.6 mg-$O_2/m^2/h$). In July, data are missing from three stations, and three others had apparent values of zero. Missing data resulted because of a wide variety of technical difficulties with the domes.




**ANALYSIS OF VARIANCE RESULTS**

**LIGHT-DARK OXYGEN CHANGE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0174 |
| Location | .0681 |
| System | .0117 |
| Loc X Syst | .2216 |

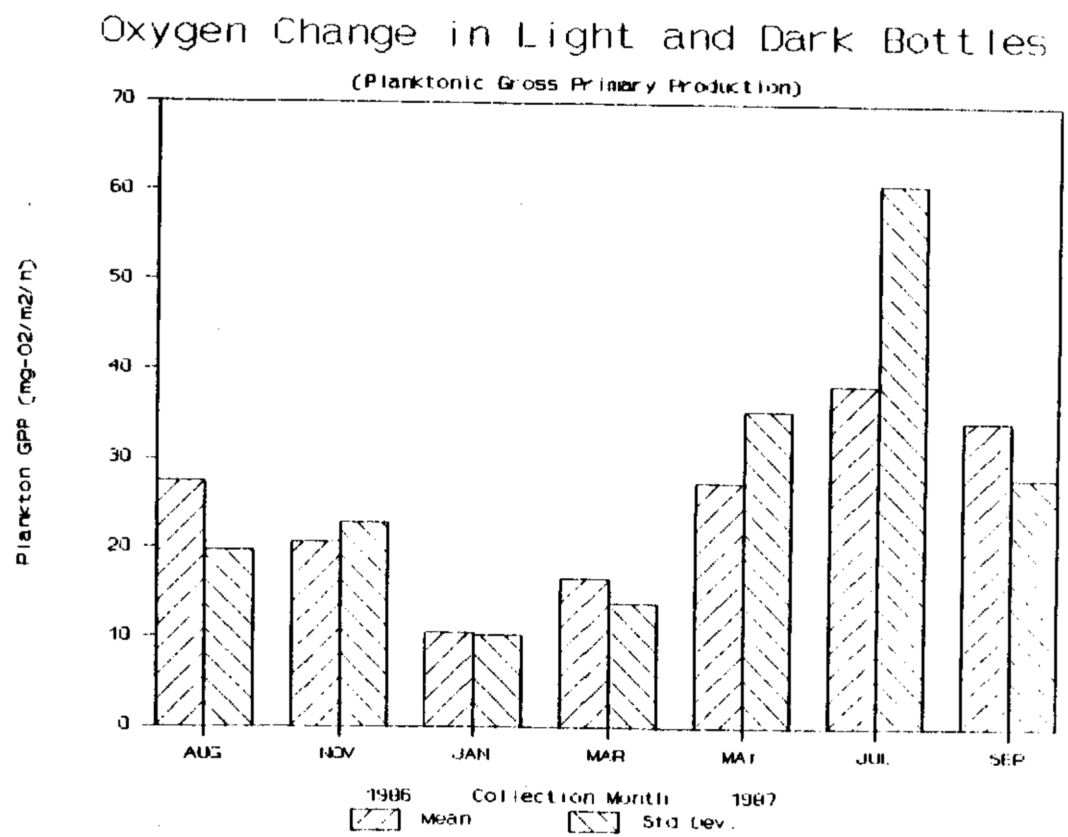
**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | A |
| 2 | A |
| 3 | A |
| 4 | A |

Figure 71



28




**ANALYSIS OF VARIANCE RESULTS**

**LIGHT-DARK OXYGEN CHANGE**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .6569 |
| Date | .4246 |
| Loc X Date | .6876 |

Figure 72



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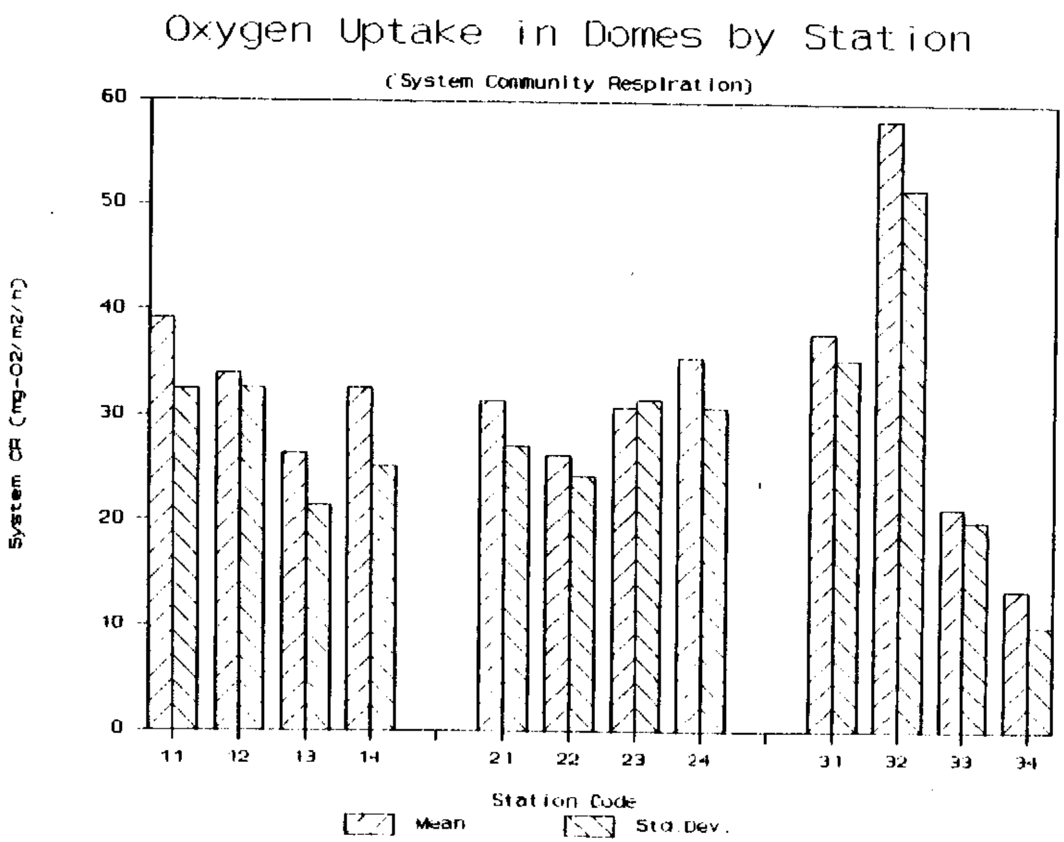



**ANALYSIS OF VARIANCE RESULTS**

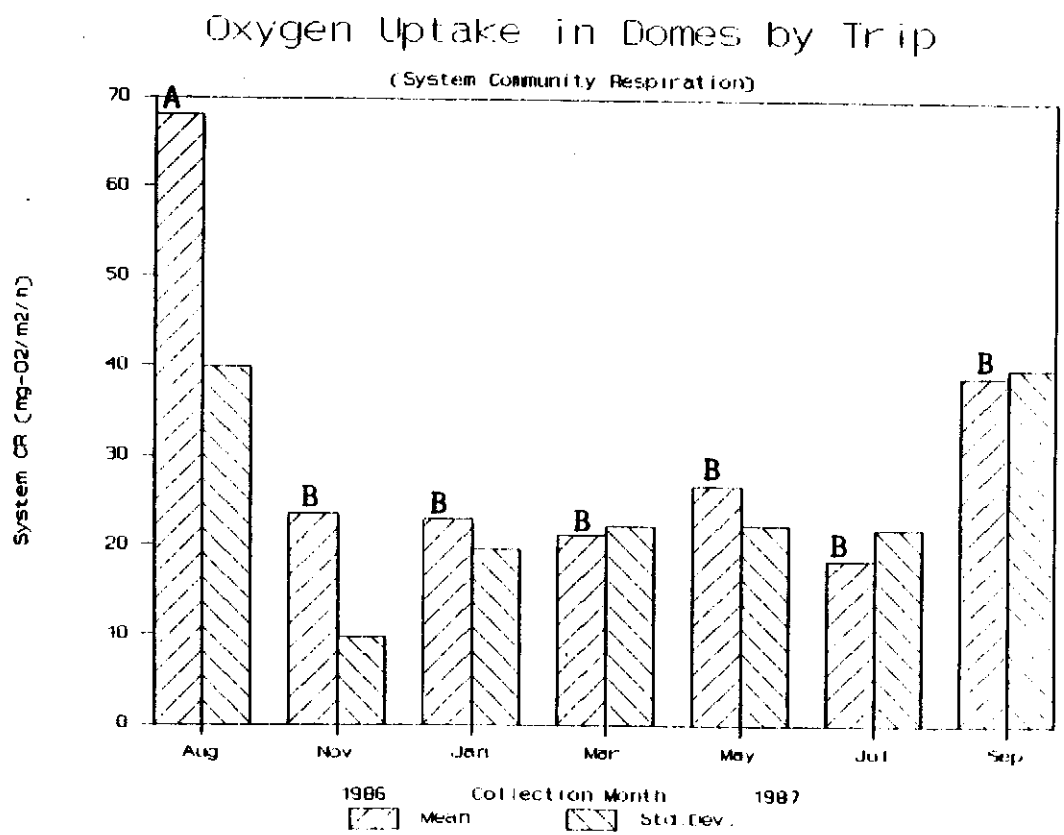
**OXYGEN UPTAKE IN DOMES**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .7104 |
| Location | .5140 |
| System | .9818 |
| Loc X Syst | .4744 |

**WALLER-DUNCAN GROUPING**

| Location | Group |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |

Figure 73




**ANALYSIS OF VARIANCE RESULTS**

**OXYGEN UPTAKE IN DOMES**

| Fixed Effect | Significant Probability |
|---|---|
| Model | .0860 |
| Date | .0019 |
| Loc X Date | .6737 |

Figure 74



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Zero values may have sometimes also resulted from these difficulties. Missing data occurred in 7 out of 84 station-trip observations. Zero values occurred in an additional 4 observations.

# DISCUSSION

## Upstream vs Outer Stations

Variation in salinity that includes frequent changes from freshwater to marine conditions may account for the sparse benthic communities at upstream stations. Upstream stations had both lower mean salinity and much more variable salinity than outer stations.

The overall design objective of this study was to replicate salinity gradients in three similar streams in northeast Florida Bay, two of which were more likely to be influenced by future modifications of C-111 canal. By monitoring along salinity gradients it was hoped that what was learned could assist in understanding what would happen if salinity were to change as a result of canal modifications. In order to decrease the chances that any differences along this salinity gradient were instead due to other confounding variables, an attempt was made to select stations to be as similar as possible in other respects. Of the environmental parameters measured, salinity mean and variation are the most consistently and most dramatically changing along the gradient.

Many of the environmental parameters measured did not vary systematically or significantly from upstream to outer stations (see Appendices A and B). Among these were physical characteristics of the stations, such as average water depth, average water-level fluctuation, sediment thickness, sediment organic content, and sediment particle size distribution. Weather



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and average surface water temperature varied from trip to trip, but not from station to station. Light extinction, pH, BOD, plankton metabolism, orthophosphate, and the morning dissolved oxygen content of water also did not vary from upstream to outer stations.

Other environmental parameters, however, did change significantly along the salinity gradient, including: daily change in dissolved oxygen, the oxygen level in the afternoon, and total open water oxygen metabolism (lower upstream), total nitrogen, total phosphorus, and ammonium concentrations (higher upstream), variation in total nitrogen and ammonium concentrations (higher upstream), total suspended solids (lower upstream), and bottom water temperature (slightly higher upstream). Undoubtedly some of these are not independent of the vegetation changes that occurred from outer to upstream stations, and should not be considered causes of the lower biotic development upstream. Lower oxygen change and higher nutrients, for example, are likely consequences of lower stocks and production of vegetation at upstream stations. Photosynthesis by the vegetation can rapidly re-aerate the water as demonstrated in the diurnal curve from Snook Creek taken in April 1986, a time before the large quantities of vegetation disappeared.

It is difficult to imagine a mechanism for how lower total suspended solids could cause lower vegetation. The lower TSS is probably simply a reflection of the generally quieter conditions of the upstream ponds. From our experience in the area, work of the wind is undoubtedly less at upstream stations, despite the lack of a clear difference among stations in our crudely measured wind speed data. Upstream stations are generally better protected by surrounding mangroves than the more open outer stations, so fetch is lower upstream.



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Upstream stations tended to be stratified, quiet "oxidation" ponds. Some but not all upstream stations exhibited very low dissolved oxygen levels on occasion, and upstream stations more rarely reached saturation levels for oxygen than did outer stations. The higher levels of total nutrients and ammonium are consistent with the "oxidation" pond concept, where reduced nutrients would be expected to be regenerated more than incorporated into biota.

Of the parameters measured that systematically and significantly vary with location, the ones most likely to account for the lower biotic development at upstream stations are mean bottom salinity, bottom salinity variation (standard deviation), and bottom water temperature. Significant regressions of both total vegetation and total fauna were found with each of these variables (Figures 75-77). Standard deviation of bottom salinity is the best regression variable. Much less biotic development occurred at stations that were more highly variable in bottom salinity over time. Variation among stations of the standard deviation of bottom salinity explains 63% and 66% of the station-to-station variation in total vegetation and total fauna, respectively, whereas variation among the twelve stations in mean bottom salinity explains only 36% and 58%. Surprisingly, the very small variation among stations in mean bottom water temperature explains 61% and 43% when regressed alone.

A SAS stepwise multiple linear regression of the log of total vegetation vs standard deviation of bottom salinity and mean bottom water temperature yielded partial r-square values of 63% and 17% respectively. A similar regression of the log of total benthic fauna, however, did not incorporate bottom water temperature for lack of effect.



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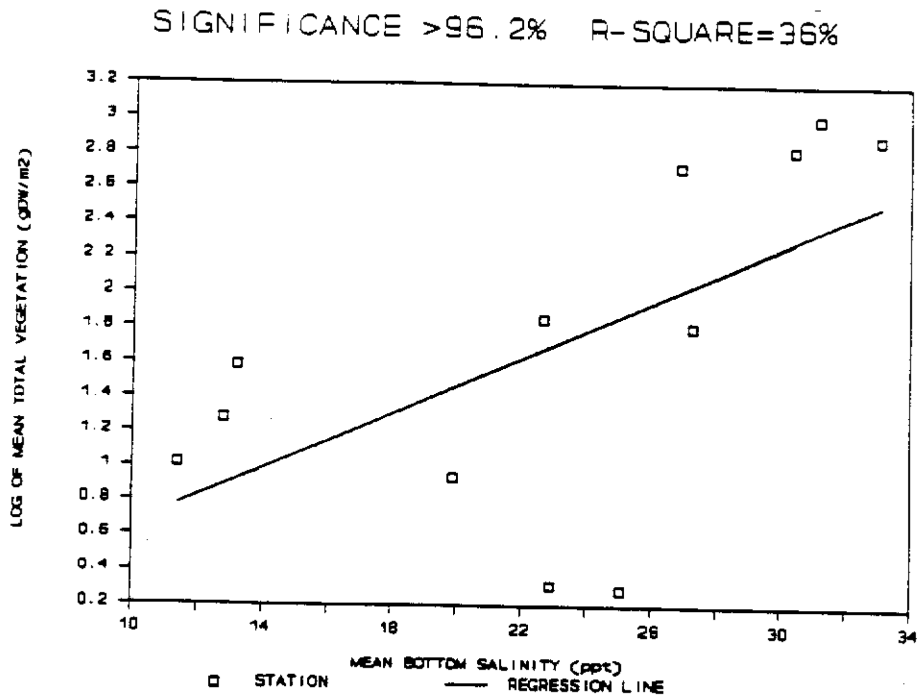
a)




b)

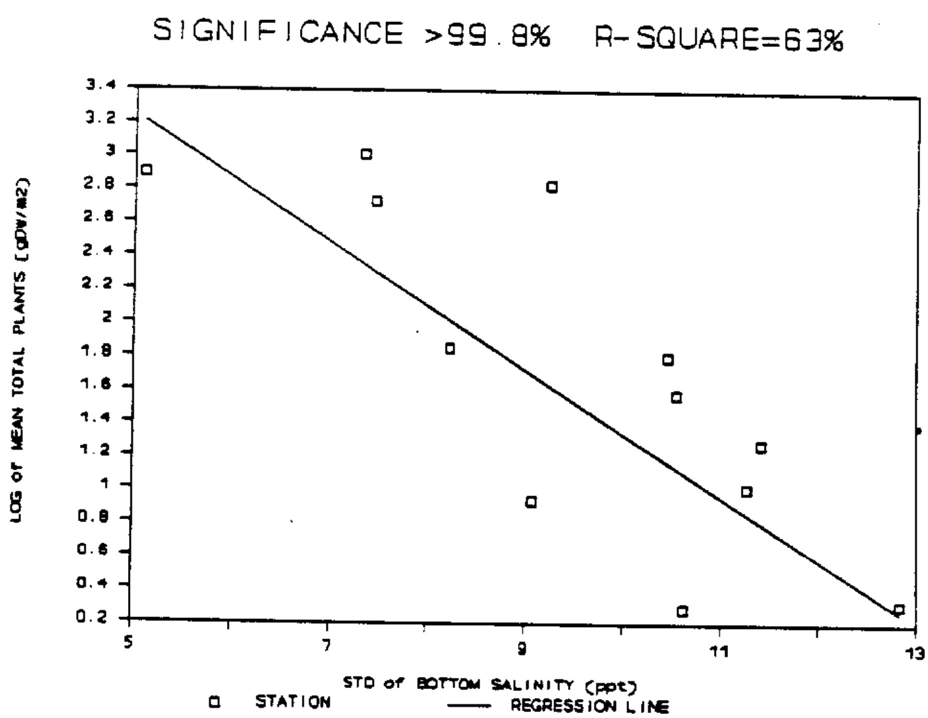



Figure 75. a) log (base 10) of mean total plants vs mean bottom salinity; b) --- vs standard deviation of bottom salinity.



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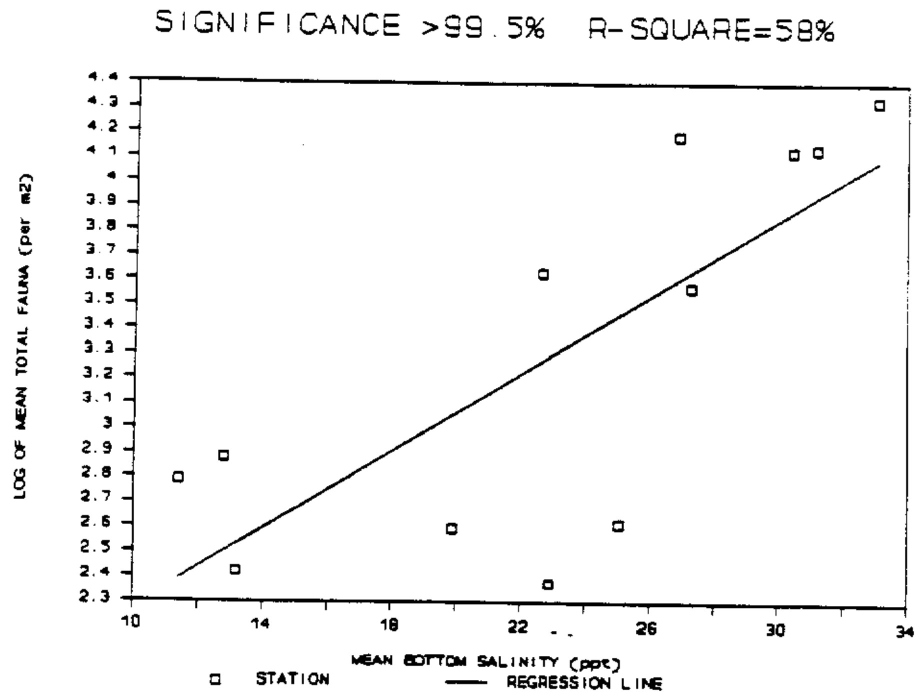
a)




b)

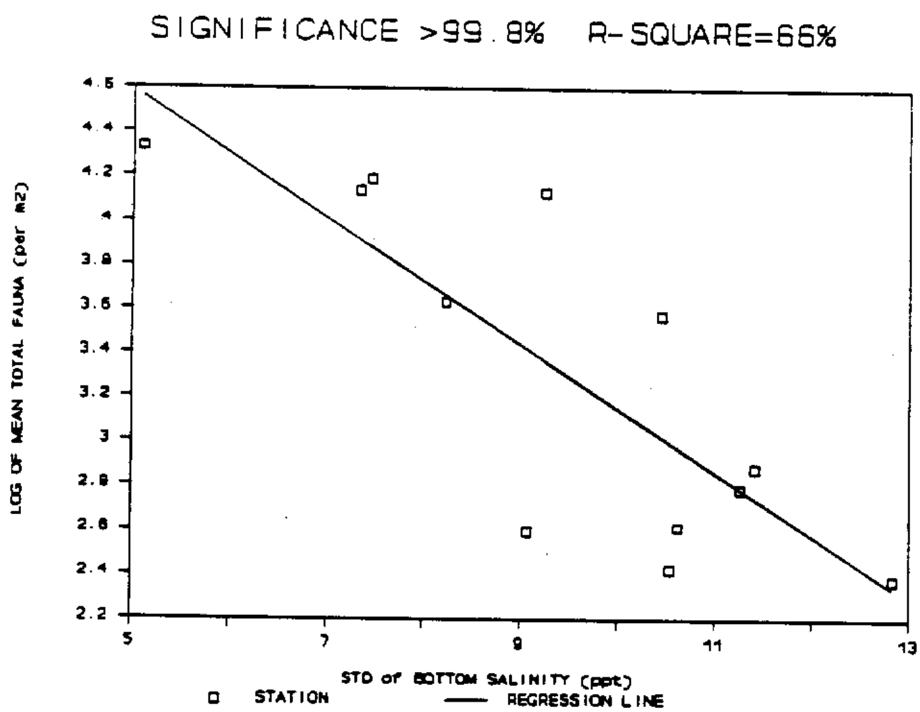



Figure 76. a) log (base 10) of mean total fauna vs mean bottom salinity; b) --- vs standard deviation of bottom salinity.



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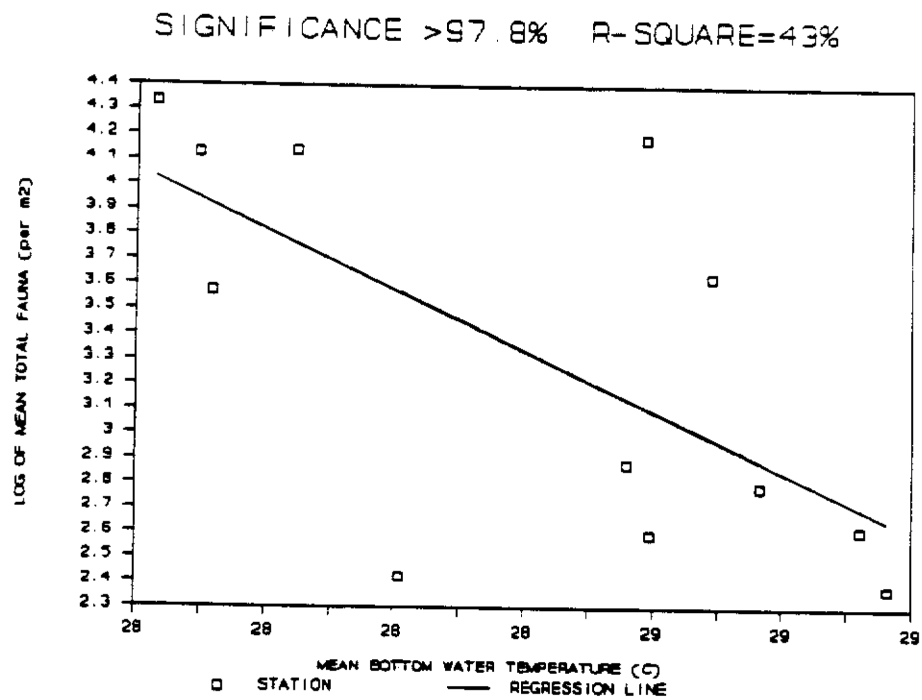
a)




b)

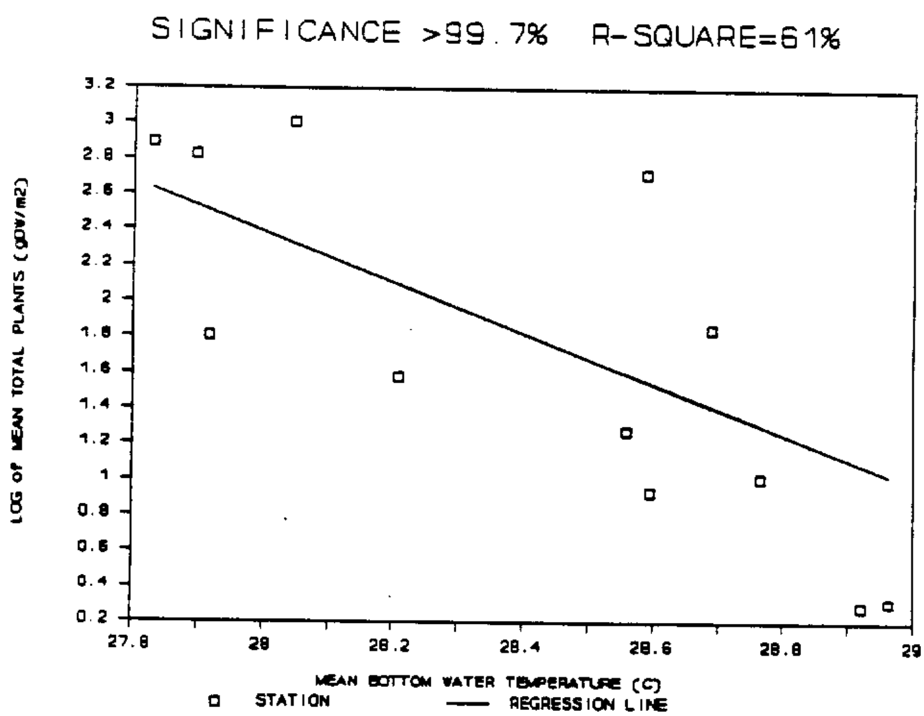



Figure 77. a) log (base 10) of mean total fauna vs mean bottom water temperature; b) log (base 10) of mean total plants vs ---.

The differences in mean bottom salinities found among the stations do not by themselves seem likely to create such dramatic differences in biotic development. Submerged vegetation found in small quantity at the upstream stations, such as Chara hornemanii, and Ruppia maritima, are known to thrive elsewhere at salinities comparable to the mean salinities found at those stations (e.g., Phillips 1960, Hoese 1960, Tabb and Manning 1961). Frequent, large, and sudden variations in salinity at a station, however, might reset succession, preventing good development of any one benthic community. Perhaps the effect is enhanced at slightly higher temperatures, thus accounting for the significant regression with bottom temperature. An interplay of Chara, Ruppia, and Halodule under conditions of changing salinity was apparent at some of our upstream stations and has been previously described at several other locations both in Florida and in Texas (Phillips 1960, Hoese 1960, Tabb and Manning 1961).

Despite an extensive literature search, quantitative studies of the responses of the types of plants that grow in these upstream stations to salinity changes of differing degrees of frequency, magnitude, or suddenness have not been found in published literature. Such information would considerably enhance understanding of the effects of water management decisions on benthic community development.

## East-to-West Differences

Some differences were noticeable among the three systems (see Appendix A, sorted by System Effect). Salinity was lower on average in the eastern system (Highway Creek to Little Blackwater Sound) and higher in the western system (Taylor River to Little Madeira Bay). Discharge of water from the upstream runs was highest in the eastern system and lowest in the western system. _Thalassia_ significantly increased from east to west. Other east-to-west patterns were not as clear, however. Outer stations in the western system had greater open water oxygen metabolism, more submerged vegetation, and more benthic animals, but western upstream stations had less than the corresponding stations of the other two systems. Thus, the benthic biological differences between upstream and outer stations were greatest in the western system.

The degree to which these east-to-west differences among the three systems can be attributed to the C-111 canal requires a greater hydrological understanding of the canal basin and the Taylor River drainage system. The U.S. Highway 1 causeway apparently blocks water flow to Barnes Sound (when the C-111 canal is plugged), as judged by: the accumulation of water on the west side of the causeway, the more northerly extent of mangrove trees on the east side, and the orientation of tree islands in the region (indicating an historical flow towards Barnes Sound). Because of the causeway and the routinely plugged canal, the eastern system probably receives more fresh surface water than it would without the canal, except perhaps when the canal is unplugged (presumably when upstream flooding is a problem). This could explain the lower salinity at the eastern stations.

Also the western system (Taylor River in particular) may not be completely outside the influence of the C-111 canal. If water from the drainage basin of Taylor River drains down the canal, then Taylor River may receive less surface water than it would without the canal system. The existence of this possibility and the magnitude of any effect awaits hydrological investigation.

## Temporal Changes During the Study Period

Although it was hoped that temporal changes in benthic communities could be correlated with temporal changes in environmental variables -- thereby giving insight into what may happen following management changes in C-111 canal -- no statistically significant temporal changes were detectable in either benthic vegetation or animals. Correlation analysis results for biota, metabolism, and nutrients analyzed by location are given in Appendix C. The lack of statistical significance occurred despite significant temporal changes in many environmental parameters including salinity, despite the strong regression of biotic development with standard deviation of salinity at stations (a measure of the degree of temporal change), and despite the observation of an interplay of vegetational changes that seemed to follow salinity at a few stations, notably in Highway Creek and Snook Creek. The reason for this lack of significance is most likely due to insufficient sampling frequency of benthic animals and plants. Studies concentrating only on submerged vegetation could conceivably provide sufficient sampling frequency at a reasonable cost, but the inclusion of the very tedious-to-sort benthic fauna samples precluded this in the present study.

A more intensive study of the upstream stations, which include continuous records of bottom water salinity and temperature and weekly monitoring of benthic vegetation, would more likely quantitatively reveal the relationship of salinity changes to vegetational changes. Factors controlling the development of healthy communities of benthic vegetation may also control the development of healthy animal communities, since the



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vegetation simultaneously provides abundant cover and food. In a regression analysis of animals vs plants, variation among the twelve stations in total biomass of submerged vegetation explained 83% of the variation in density of benthic fauna.

Generally, the temporal changes recorded during the study period follow seasonal changes in temperature, rain, and wind. January 1987 was the coolest trip, August 1986 was the stormiest trip, and March 1987 was also windy, with some rain. The summer of 1987 appeared to be atypically dry, as reflected in the increasing salinity throughout the end of the study period (September 1987). The significant increase in pH in July 1987 may be due to a combination of saltier water and greater primary production. During 1987, nutrients in water also steadily increased, and at many stations, submerged vegetation did not seem to be as great as in 1986. Higher nutrients in water could be explained by their being not limiting (and acting conservatively as does the salt content of water), or by accumulating in plankton as the benthic vegetation failed to grow (a shift of ecological production). The increase in total phosphorus in water and the high planktonic production in September 1987 are suggestive of such a shift.

The benthic plants and animals of the region are spatially dynamic and are likely to be highly responsive to environmental changes. Salinity is not only perhaps the most physiologically influential environmental parameter in Florida estuaries, but it is also the parameter most likely to change with canal alterations. Since natural fluctuations in this parameter are only as predictable as the weather, a large data base of the range of responses to this parameter will be necessary to ensure detection of the effects of canal alterations -- unless the alterations create very large changes. More



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insidious alterations, however, will go undetected for a much longer time (Odum 1970).

## Submerged Vegetation

Although vegetation dramatically declines from outer to upstream stations, even the vegetation at the outer stations is relatively sparse compared to elsewhere in Florida Bay. To the south and west in Florida Bay, mean biomass for *Thalassia*-dominated seagrass communities ranged from 1100 to 2700 $g/m^2$, with values to 8100 $g/m^2$ (Zieman 1982). The station with the greatest mean biomass was Little Madeira Bay at Taylor River with 1023 $g/m^2$. Seagrasses accounted for only 69% of the average weight; 30% was from the calcareous green algae *Udotea*.

The stations with the most *Thalassia* were Little Madeira Bay Hydrostation (720 $g/m^2$), Northeast Trout Cove (670 $g/m^2$), and Little Madeira Bay at Taylor River (400 $g/m^2$). The outer stations, however, often contained comparatively very high biomass of calcareous green algae. The 300 $g/m^2$ of *Udotea* reported for Little Madeira Bay at Taylor River and the 437 $g/m^2$ of *Penicillus* at Northeast Little Blackwater Sound is very much higher than average values for *Penicillus* in Florida Bay reported by Stockman et al. (1967). Their estimate of 2 plants per $m^2$ with an average aragonite content of 0.52 g per plant yields and average dry biomass of only 1.2 $g/m^2$ if *Penicillus* is assumed to be 85% aragonite. If their estimate did not include the below-ground portions (which made up 70% of the total dry weight in our samples), then a value of 4.0 $g/m^2$ would be a more comparable average value. Because of the high aragonite content of these algae, however, their organic content is much lower than comparable weights of seagrasses. Their primary ecological importance may be more in sediment formation (Stockman et al. 1967) and in providing cover for small animals than in providing organic matter to a food chain.

The outer stations represent only a small portion of the sounds and bays of which they are a part. Because they were selected to minimize differences with the upstream stations (except salinity), they are shallower and contain thicker sediments than are generally present in their respective bays and sounds. As such they are more similar to the shallow banks that separate deeper basins or "lakes" elsewhere in Florida Bay. These banks typically have more vegetation than basins (Stockman et al. 1967, Zieman and Fourqurean, in press), so the biomass at the outer stations may overestimate the biomass of the region in general.

Vegetation types at the upstream stations are typical of brackish conditions elsewhere in Florida (Tabb and Manning 1961, Phillips 1960), though quantities are much lower than in areas where these species grow well. Even the atypically dense, mixed stands of <u>Ruppia</u>, <u>Chara</u>, and <u>Batophora</u> in Snook Creek during March, April, and May 1986 (which ranged from 80 to 250 $g/m^2$) are not within the high range of biomass reported for <u>Ruppia</u>. World wide, good stands of <u>Ruppia</u> range in biomass from 500 to 1000 $g/m^2$ (Verhoeven 1980).

At the upstream sites, species changes occurred very quickly (within the two-month sampling frequency), evidently in response to changes in salinity. Apparent changes in species composition at outer stations were confounded by the greater spatial patchiness there, but perhaps occurred with algal species (e.g. <u>Udotea</u>). At the upstream stations, <u>Ruppia</u>, <u>Chara</u>, and <u>Halodule</u> were involved. <u>Ruppia</u> and <u>Halodule</u> can apparently expand into the area very quickly when conditions are suitable (Phillips 1960, Zieman 1982). We were unable to detect rhizomes of these plants when their shoots were absent, though it is possible that some went undetected, or were incorrectly identified. Identification of the poorly developed shoots and rhizomes at these sites was difficult on some occasions. Nevertheless, an interplay of Ruppia, Chara, and Halodule in response to changing salinity has been described several times before: in Coot Bay, Florida (Tabb and Manning 1961); in Old Tampa Bay, Florida (Phillips 1960); and in Mesquite Bay, Texas (Hoese 1960). In all of these accounts, as in our study, Halodule appeared at higher salinities (> 25 ppt) and Ruppia appeared at lower salinities.

It is unclear why the vegetation in Snook Creek, which was so abundant during our first three trips (March, April, and May 1986), disappeared, never to return on any of our subsequent trips. Salinity in Snook Creek rose during the first three trips from 13 ppt to 26 ppt, but by June had dropped to 1 ppt, where it remained at least until August. In Coot Bay, Florida, the best stands of Chara and Batophora reportedly occurred when salinities were below 15 ppt (Tabb and Manning 1961). The best stands of Ruppia occurred below 25 ppt in Tampa Bay (Phillips 1960) and below 28 ppt in Florida Bay (Tabb and Manning 1961). High salinity, or salinity shock (if salinity suddenly dropped) may have caused a die-off of vegetation in Snook Creek, but other factors cannot be eliminated. A manatee, for example, was observed in Snook Creek in July 1986, our first visit after the vegetation disappeared. This observation led to an alternate hypothesis that a manatee could have consumed all of the vegetation in Snook Creek. Judging from published accounts of manatee feeding rates and preferences (Etheridge, et al. 1985), and the relatively small size of these ponds, such a possibility is not unreasonable.

The dense mats of the filamentous bluegreen alga Lyngbya that appeared in Snook Creek following the disappearance of the macrophytes are perhaps similar to those reported in Tampa Bay and Indian River, Florida by Phillips (1960). Phillips found a consistent ontogeny of these Lyngbya mats that is consistent with our own observations. In Phillips' observations, the mats grew rapidly. Gas bubbles produced within the mat, however, caused portions to dislodge and float away. Although the fate of the mat in Snook Creek is unknown, floating portions of benthic mats were often visible both in Snook Creek Pond 3 and in Taylor River Pond 3 during our visits. It is possible that Lyngbya was commonly present at upstream stations in Taylor River, but was never dense enough to be serendipitously sampled by our macrophyte collection procedures, as was the case in Snook Creek. Special sampling procedures must be employed if microalgal communities are to be quantified.

## Benthic Fauna

Considerable variation occurs among reported densities of benthic fauna owing to variation not only in location, but also in sampling methods. In most studies, however, annelids (primarily polychaetes), arthropods (primarily crustaceans), and mollusks are perhaps always the most common phyla represented in estuarine benthic samples. The overall density of benthic macrofauna found by Homziak et al. (1982) in a Zostera meadow along the mid-Atlantic coast was 4100 - 8500 per $m^2$. They sampled with cores and used a 0.5 mm sieve. These values are somewhat higher than those found by Nelson (1981) in a seagrass bed dominated by Halodule in Indian River Lagoon, Florida (500 - 3800), who also used cores, but used a 1.0 mm sieve. Polychaetes alone accounted for 7450 - 20,680 individuals per $m^2$ in Tampa Bay cores sieved through a 0.5 mm sieve (Santos and Simon 1974). Polychaetes and amphipods together accounted for 1170 individuals per $m^2$ in dredged cores from Card Sound (Brook 1977).

Although our samples initially appear to be similar in number to these studies (17,000 per $m^2$ at outer stations, mean of 6000 per $m^2$), they become much lower in more careful comparison. The above studies employed cores, yet most of our animals were collected in epifauna nets. The overall mean density of benthic fauna from our cores alone was only 1160 individuals per $m^2$, considerably lower than those of the other studies, but similar to the total of amphipods and polychaetes alone found in cores from Card Sound by Brook (1977).

Our screen size used for sieving cores, however, was an atypical 2.0 mm mesh, which eliminated a considerable number of very small animals, perhaps as many as 3300 per $m^2$, as judged by the 10% of samples that were analyzed through a 1 mm mesh. An adjusted estimate from our cores of 4460 per $m^2$ from cores is comparable to values found in Indian River (Nelson 1981), but is still much lower than the estimate from Tampa Bay (Santos and Simon 1974). All material passing through the 2 mm sieve has been saved for later analysis if future research requires this.

Lewis et al. (1984) reported benthic crustaceans from cores taken from several types of substrate in north Florida. Cores within well-developed communities dominated by <u>Halodule</u> or <u>Thalassia</u> contained the most crustacea (6453 and 6973 per $m^2$, respectively), while cores from bare patches within <u>Thalassia</u> beds and barren areas away from vegetation contained far fewer

(2203 and 432 per $m^2$, respectively). A strong correlation of vegetation and benthic fauna is apparent in our study (r-square of 83%). Although such a correlation may relate partially to the enhanced presence of food and cover among the seagrasses, rigorous environmental conditions at upstream stations (i.e., salinity variation) may independently cause low densities of both submerged vegetation and benthic fauna.

## Oxygen Metabolism

Open-water oxygen change is an estimate of daytime aquatic net community production and oxygen uptake in domes is an estimate of community respiration. The addition of these is therefore an estimate of the daytime gross primary production of the entire aquatic system (Table 8). The overall average gross primary production of 149 mg-$O_2/m^2/h$ is equivalent to about 188 g of carbon fixed per $m^2$ per yr if an average daylength of 12 h is assumed and approximately 1.3 mol of $O_2$ released for every mol of $CO_2$ fixed (photosynthetic quotient of 1.3; Valiela 1984). This value is comparatively very low for estuarine gross production. Odum (1963) reports gross primary production values for shallow estuaries of 500 to 1250 g-$C/m^2/y$.

The average community respiration rate as measured in the domes is approximately equivalent to 105 g-$C/m^2/yr$, (using a respiratory quotient of 1 and assuming the respiration applies 24 hours per day). This is also a comparatively low value; whole-system respiration in Naragansett Bay, Rhode Island was 360 g-$C/m^2/yr$ (Nixon et al. 1976).

Planktonic gross production of 25 mg-$O_2/m^2/h$ is approximately equivalent to 32 g-$C/m^2/yr$, using the same assumptions as for whole-system gross primary production. This too is a very low value compared to other studies of



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Table 8. Average oxygen metabolism (mg-$O_2$/m2/h) at the two upstream and the two outer stations (NCP is daytime net community production, CR is community respiration, GPP is gross primary production).

| Stations | ----- System ----- | | | --------- Daytime GPP --------- | | |
|---|---|---|---|---|---|---|
| | NCP | CR | P/R* | System | Planktonic | %-Plankt. |
| Upstream | 50.7 | 26.7 | 1.4 | 77.4 | 34.0 | 44 |
| Outer | 182.3 | 37.9 | 2.9 | 220.2 | 16.2 | 7 |
| Average | 116.5 | 32.3 | 2.3 | 148.8 | 25.1 | 17 |

* P/R = System-GPP/(2 x System-CR).



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Frequency and amplitude of variation should also be independently tested. This could be accomplished by sampling a large number of sites where salinity has been monitored and by using test-chambers in a laboratory, where salinity regime can be controlled.

If developed and proven, however, the management principle outlined above should allow engineers to consider estuarine impact at the design phase of canals and canal modifications. This should then reduce the expense of (if not eliminate) trial-and-error monitoring programs designed to evaluate impact after the fact.

planktonic production. Whittle (1977), for example, reported an average value of 682 g-C/$m^2$/yr for <u>net</u> production, which is usually considerably lower than gross (Goldman 1968). Even in the open sea, where production is very low, average net production is higher than our value for gross production. Open-ocean net production is approximately 50 g-C/$m^2$/yr (Ryther 1969).

Although there are perhaps 50 times more animals and dry mass of submerged vegetation at outer stations, as shown in Table 8, gross production at outer stations is only about 2.8 times that of upstream stations, a statistically significant increase (>99.9% confidence). Benthic and planktonic microbial communities at the upstream stations may account for considerable production and respiration. Plankton production as measured by our light-dark bottle method is in fact more than twice as high at upstream stations than at downstream stations. Plankton production also accounts for a far greater percentage of total production at upstream stations (44% as compared to 7%). The ratio of gross production to 24-hr community respiration (P/R ratio) is also much lower at the upstream sites. Upstream sites respire almost as much as they produce, leaving little for export or burial in sediments. Outer stations produce perhaps three times more than is consumed there. Although production is lower at the upstream stations, respiration is still nearly as high, yet macrofauna numbers are very low. Microbial decomposers often account for considerable respiration in estuarine ecosystems. In a Georgia salt marsh, for example, microbes respire one-third of the net photosynthesis in the marsh (Wiegert 1979). Additional studies of the stations will be necessary to evaluate the microbial portion of this community.

## Nutrients in Water

Total phosphorus concentrations at our stations were very low (mean of 0.5 uM - 15.6 ug/l). In Rookery Bay, Florida, orthophosphate alone averages around 1.0 uM and in Charlotte Harbor, Florida, orthophosphate averages 7 uM (Fanning and Bell 1982). In Tampa Bay, orthophosphate increased from 9 to 40 uM between 1972 and 1981 (Fanning and Bell 1982). Our values are one-thirteenth the values reported for the Indian River, Florida (Montgomery et al. 1983, Steward and VanArman 1986). The average nitrogen to phosphorus ratio of 313:1 is indicative of severe phosphorus limitation. Most estuaries and nearshore zones along the Atlantic coast north of Florida are nitrogen limited (Ryther and Dunstan 1971, Haines et al. 1977), but clearer Florida estuaries may tend to be phosphorus limited (e.g. Short et al. 1985). The more northerly estuaries tend to be turbid owing to considerable river inputs of sediment from piedmont-draining rivers (Meade et al. 1975, Postma 1980). These iron-rich sediments bind phosphorus which is then released in the anaerobic sediments of the coastal zones (Patrick and Khalid 1974). Our stations in northeast Florida Bay contain calcium carbonate marl and probably little iron or available phosphorus (see Rosenfeld 1979, Gaudette and Lyons 1980). Nutrients from upstream drainage are perhaps stripped out of water as it flows over marshes to the north, or is sequestered in the carbonate marl of northeast Florida Bay (Gaudette and Lyons 1980). Sedimentary phosphorus may be extracted by seagrass roots and released to the water column through leaves, where it may be quickly used by epiphytic algae and phytoplankton.

The nutrient data provided in this study were collected along with many other environmental factors which could potentially affect ecosystem



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development or confound effects of salinity. No evidence has been gathered that the surface waters entering northeast Florida Bay are providing significant levels of nutrients to the bay. The slightly elevated levels of nutrients sometimes observed at upstream stations could be due to such an input, which is diluted in the larger volume of water in the bay, but it could also be due to less utilization of the same amount of nutrients at the less productive upstream stations. If the inflowing water was providing nutrients, a negative correlation would be expected between salinity and total nitrogen and phosphorus, especially at the upstream stations, where vegetation was sparse and production low. No such correlation was apparent in our data.

Understanding the potential and realized effects of C-111 canal on delivery of plant nutrients to Florida Bay will require special studies of nutrients in both sediments and water, the rates of exchange between the two, the ecological demand for nutrients, and the portion of the demand that is met by recycling (as opposed to newly imported nutrients). Such studies should include sampling during high winds and separately during high water flows. Sediments resuspended by winds may provide nutrients to the water independent of any influx from surface water. If sufficient evidence for phosphorus limitation is obtained, nitrogen studies may become less relevant. Studies of phosphorus cycling are technically much simpler because of the general lack of a gaseous phase in nature (nitrogen studies require estimates of nitrogen fixation and denitrification).



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## Hypothesis of a Management Principle

Control of salinity fluctuation is perhaps the key to controlling impact of freshwater delivery on estuarine animals and plants. A combination of salinity mean and salinity variation most likely accounts for the dramatic declines in submerged vegetation, benthic fauna, and overall metabolism measured along the three salinity gradients established in northeast Florida Bay. At the upstream sites, salinity seems to vary suddenly and frequently enough that infant communities are killed by salinity shock before development can proceed very far. Furthermore, it may be that salinity variation of the same magnitude causes more dramatic changes when mean salinity is lower, perhaps because variation within more marine conditions (say 15 to 25 ppt) is more physiologically tolerable than similar variation between fresh and 10 ppt, where freshwater physiology may become necessary and freshwater competitors may appear. If this is true, then the frequency of appearance of freshwater (zero ppt) at a site should be a most important parameter in benthic community development. Understanding such parameters will lead to principles of water management for controlling, or preserving estuarine benthic community development and perhaps estuarine ecosystem development in general. Thoroughly testing this knowledge, however, is essential before the hypothesis is assumed to be true and the management principle prematurely applied.

Testing the above hypothesis of the combined effects of salinity mean and salinity variation will require the observation of benthic community development in areas of similar salinity variation, but with differing mean salinities and in areas of similar mean salinity, but differing variation.

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APPENDIX A. General Results of SAS ANOVA Models LOCMOD.SAS and DATEMOD.SAS

******* LOCMOD.SAS Results Sorted by LOCATION *******

| | VARIABLE | FIGURE# | (Pr>F) LOCMODEL | (Pr>F) LOCATION | (Pr>F) SYSTEM | (Pr>F) LOCxSYST |
|---|---|---|---|---|---|---|
| | [1] PLNT_TOT | 58 | 0.0001 | 0.0001 | 0.0107 | 0.0006 |
| | [1] SAL_SRF | 2 | 0.0001 | 0.0001 | 0.0002 | 0.8508 |
| | [1] FAUN_TOT | 61 | 0.0012 | 0.0001 | 0.2583 | 0.7961 |
| | [1] SAL_BOT | 4 | 0.0001 | 0.0001 | 0.0001 | 0.8458 |
| | [1] ARTHROPO | 58 | 0.004 | 0.0001 | 0.7982 | 0.7615 |
| | [1] OWMETAVG | 69 | 0.0001 | 0.0001 | 0.0075 | 0.26 |
| | [1] EPINET_F | . | 0.0038 | 0.0001 | 0.249 | 0.8048 |
| | [2] HALODULE | . | 0.0001 | 0.0001 | 0.0774 | 0.0001 |
| | [1] MOLLUSKS | 68 | 0.0001 | 0.0001 | 0.2142 | 0.0073 |
| | [1] PENICILLU | . | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | [1] SHCORE_F | . | 0.0001 | 0.0001 | 0.7912 | 0.371 |
| | [1] DO_PCT_L | 36 | 0.0001 | 0.0001 | 0.0273 | 0.0055 |
| | [1] THALASSI | . | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | [3] SED_DPTH | 15 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | [1] SIPUNCUL | . | 0.002 | 0.0001 | 0.1521 | 0.6389 |
| | [2] HALIMEDA | . | 0.0001 | 0.0001 | 0.3419 | 0.3725 |
| | [1] NEMERTEA | . | 0.0028 | 0.001 | 0.1158 | 0.1235 |
| | [1] VERTEBRA | . | 0.3106 | 0.0016 | 0.9671 | 0.2073 |
| >99% | [1] DPCORE_F | 64 | 0.0061 | 0.0094 | 0.0273 | 0.1613 |
| | [1] ECHINODE | . | 0.0157 | 0.0112 | 0.127 | 0.1448 |
| | [1] DOME_FAU | 63 | 0.1974 | 0.0121 | 0.534 | 0.8893 |
| >95% | [1] DO_CHNG | 34 | 0.2669 | 0.0454 | 0.2364 | 0.8707 |
| | [1] LDMET_M2 | 71 | 0.0174 | 0.0681 | 0.0117 | 0.2216 |
| | [1] CNIDARIA | . | 0.1865 | 0.0833 | 0.3562 | 0.3761 |
| >90% | [1] TOTAL_N | 54 | 0.2328 | 0.0989 | 0.2374 | 0.5477 |
| | [2] SEDCLAY | 19 | 0.1008 | 0.1008 | . | . |
| | [1] PH | 10 | 0.3153 | 0.1009 | 0.4962 | 0.5341 |
| | ANNELIDS | 68 | 0.1804 | 0.1047 | 0.1179 | 0.5528 |
| | [2] SEDSILT | 19 | 0.1081 | 0.1081 | . | . |
| | NP_RATIO | 56 | 0.187 | 0.1238 | 0.2489 | 0.3645 |
| | LT_SRF | . | 0.3736 | 0.1538 | 0.0888 | 0.9456 |
| | REL_HUM | . | 0.1867 | 0.1762 | 0.3027 | 0.2517 |
| | DPTH_AVG | 12 | 0.0001 | 0.177 | 0.0935 | 0.0001 |
| | [2] UDOTEA | . | 0.026 | 0.1899 | 0.1067 | 0.0394 |
| >80% | TSS_SRF | 27 | 0.7956 | 0.1919 | 0.7175 | 0.9635 |
| | CHARA | . | 0.3717 | 0.2819 | 0.2047 | 0.5727 |
| | LAURENCIA | . | 0.14 | 0.2944 | 0.2085 | 0.1517 |
| | CHAETOGN | . | 0.3408 | 0.3175 | 0.3715 | 0.333 |
| | SED_ORG | 17 | 0.6553 | 0.3216 | 0.7986 | 0.6229 |
| | SEDSOLUB | 18 | 0.3486 | 0.3486 | . | . |
| | BATOPHOR | . | 0.1191 | 0.3615 | 0.0626 | 0.2178 |
| | LYNGBYA | . | 0.2484 | 0.3751 | 0.248 | 0.2416 |
| | NH4 | 52 | 0.6885 | 0.3819 | 0.202 | 0.9272 |
| | TOTAL_P | 50 | 0.9018 | 0.4485 | 0.9705 | 0.8412 |
| | ACETABUL | . | 0.3658 | 0.4592 | 0.3156 | 0.3341 |
| >50% | SEDMOIST | 16 | 0.4789 | 0.4789 | . | . |
| | DPTH_CHN | 14 | 0.2888 | 0.5127 | 0.0447 | 0.595 |
| | DOME_MET | 73 | 0.7104 | 0.514 | 0.9818 | 0.4744 |
| | RUPPIA | . | 0.5003 | 0.5366 | 0.2451 | 0.4961 |
| | EARLY_DO | 33 | 0.298 | 0.5456 | 0.2376 | 0.2397 |
| | SARGASSU | . | 0.6407 | 0.5664 | 0.2261 | 0.7122 |
| | RHIZOCLO | . | 0.5815 | 0.5714 | 0.3831 | 0.4803 |
| | SEDSHELL | 19 | 0.5919 | 0.5919 | . | . |
| | CLADOPHO | . | 0.615 | 0.5966 | 0.492 | 0.4507 |
| | POLYSIPH | . | 0.4885 | 0.6391 | 0.1864 | 0.4734 |
| | SOM_SRF | 30 | 0.9873 | 0.6567 | 0.5177 | 0.9999 |
| | TSSSTRAT | 29 | 0.7193 | 0.6626 | 0.1169 | 0.9626 |
| | AIR_TMP | . | 0.973 | 0.7529 | 0.7682 | 0.9139 |
| | WTMP_BOT | 8 | 0.9982 | 0.8157 | 0.8411 | 0.9933 |
| | BOD_SRF | 46 | 0.4886 | 0.8851 | 0.0748 | 0.6071 |
| | WNDSPD | 21 | 0.9155 | 0.9326 | 0.1711 | 0.9798 |
| | LTEXCOEF | 25 | 0.938 | 0.9373 | 0.9508 | 0.6503 |
| | SOMSTRAT | 32 | 0.7912 | 0.9577 | 0.1779 | 0.8314 |
| | WTMP_SRF | 6 | 0.9999 | 0.9731 | 0.8896 | 0.9958 |
| | SEDSAND | 19 | 0.9771 | 0.9771 | . | . |
| | ORTH_PO4 | 48 | 0.9523 | 0.9822 | 0.6924 | 0.7421 |

[1] Waller Test indicates a location gradient from upstream to downstream.

[2] Waller Test run but no location gradient found.

[3] Waller Test indicates a single location at the extreme end of the gradient.



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******** LOCMOD.SAS Results Sorted by SYSTEM ********

| | VARIABLE | FIGURE# | (Pr>F) LOCMODEL | (Pr>F) LOCATION | (Pr>F) SYSTEM | (Pr>F) LOCxSYST |
|---|---|---|---|---|---|---|
| | [4] SED_DPTH | 15 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | [5] PENICILLU | . | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | [6] SAL_BOT | 4 | 0.0001 | 0.0001 | 0.0001 | 0.8458 |
| | [6] THALASSI | . | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | [7] SAL_SRF | 2 | 0.0001 | 0.0001 | 0.0002 | 0.8508 |
| >99% | [47] OWMETAVG | 69 | 0.0001 | 0.0001 | 0.0075 | 0.26 |
| | [7] PLNT_TOT | 58 | 0.0001 | 0.0001 | 0.0107 | 0.0006 |
| | [7] LDMET_M2 | 71 | 0.0174 | 0.0681 | 0.0117 | 0.2216 |
| | [7] DO_PCT_L | 36 | 0.0001 | 0.0001 | 0.0273 | 0.0055 |
| | [7] DPCORE_F | 64 | 0.0061 | 0.0094 | 0.0273 | 0.1613 |
| >95% | [47] DPTH_CHN | 14 | 0.2888 | 0.5127 | 0.0447 | 0.595 |
| | [8] BATOPHOR | . | 0.1191 | 0.3615 | 0.0626 | 0.2178 |
| | [8] BOD_SRF | 46 | 0.4886 | 0.8851 | 0.0748 | 0.6071 |
| | [8] HALODULE | . | 0.0001 | 0.0001 | 0.0774 | 0.0001 |
| | [8] LT_SRF | . | 0.3736 | 0.1538 | 0.0888 | 0.9456 |
| >90% | [6] DPTH_AVG | 12 | 0.0001 | 0.177 | 0.0935 | 0.0001 |
| | UDOTEA | . | 0.026 | 0.1899 | 0.1067 | 0.0394 |
| | NEMERTEA | . | 0.0028 | 0.001 | 0.1158 | 0.1235 |
| | TSSSTRAT | 29 | 0.7193 | 0.6626 | 0.1169 | 0.9626 |
| | ANNELIDS | 68 | 0.1804 | 0.1047 | 0.1179 | 0.5528 |
| | ECHINODE | . | 0.0157 | 0.0112 | 0.127 | 0.1448 |
| | SIPUNCUL | . | 0.002 | 0.0001 | 0.1521 | 0.6389 |
| | WNDSPD | 21 | 0.9155 | 0.9326 | 0.1711 | 0.9798 |
| | SOMSTRAT | 32 | 0.7912 | 0.9577 | 0.1779 | 0.8314 |
| >80% | POLYSIPH | . | 0.4885 | 0.6391 | 0.1864 | 0.4734 |
| | NH4 | 52 | 0.6885 | 0.3819 | 0.202 | 0.9272 |
| | CHARA | . | 0.3717 | 0.2819 | 0.2047 | 0.5727 |
| | LAURENCIA | . | 0.14 | 0.2944 | 0.2085 | 0.1517 |
| | MOLLUSKS | 68 | 0.0001 | 0.0001 | 0.2142 | 0.0073 |
| | SARGASSU | . | 0.6407 | 0.5664 | 0.2261 | 0.7122 |
| | DO_CHNG | 34 | 0.2669 | 0.0454 | 0.2364 | 0.8707 |
| | TOTAL_N | 54 | 0.2328 | 0.0989 | 0.2374 | 0.5477 |
| | EARLY_DO | 33 | 0.298 | 0.5456 | 0.2376 | 0.2397 |
| | RUPPIA | . | 0.5003 | 0.5366 | 0.2451 | 0.4961 |
| | LYNGBYA | . | 0.2484 | 0.3751 | 0.248 | 0.2416 |
| | NP_RATIO | 56 | 0.187 | 0.1238 | 0.2489 | 0.3645 |
| | EPINET_F | . | 0.0038 | 0.0001 | 0.249 | 0.8048 |
| | FAUN_TOT | 61 | 0.0012 | 0.0001 | 0.2683 | 0.7961 |
| | REL_HUM | . | 0.1867 | 0.1762 | 0.3027 | 0.2517 |
| | ACETABUL | . | 0.3858 | 0.4592 | 0.3156 | 0.3341 |
| | HALIMEDA | . | 0.0001 | 0.0001 | 0.3419 | 0.3725 |
| | CNIDARIA | . | 0.1865 | 0.0833 | 0.3562 | 0.3761 |
| | CHAETOGN | . | 0.3408 | 0.3175 | 0.3715 | 0.333 |
| | RHIZOCLO | . | 0.5815 | 0.5714 | 0.3831 | 0.4803 |
| | CLADOPHO | . | 0.615 | 0.5966 | 0.492 | 0.4507 |
| >50% | PH | 10 | 0.3153 | 0.1009 | 0.4962 | 0.5341 |
| | SOM_SRF | 30 | 0.9873 | 0.6567 | 0.5177 | 0.9999 |
| | DOME_FAU | 63 | 0.1974 | 0.0121 | 0.534 | 0.8893 |
| | ORTH_PO4 | 48 | 0.9523 | 0.9822 | 0.6924 | 0.7421 |
| | TSS_SRF | 27 | 0.7956 | 0.1919 | 0.7175 | 0.9635 |
| | AIR_TMP | . | 0.973 | 0.7529 | 0.7682 | 0.9139 |
| | SHCORE_F | . | 0.0001 | 0.0001 | 0.7912 | 0.371 |
| | ARTHROPO | 68 | 0.004 | 0.0001 | 0.7982 | 0.7615 |
| | SED_ORG | 17 | 0.6553 | 0.3216 | 0.7986 | 0.6229 |
| | WTMP_BOT | 8 | 0.9982 | 0.8157 | 0.8411 | 0.9933 |
| | WTMP_SRF | 6 | 0.9999 | 0.9731 | 0.8896 | 0.9958 |
| | LTEXCOEF | 25 | 0.938 | 0.9373 | 0.9508 | 0.6503 |
| | VERTEBRA | . | 0.3106 | 0.0016 | 0.9671 | 0.2073 |
| | TOTAL_P | 50 | 0.9018 | 0.4485 | 0.9705 | 0.8412 |
| | DOME_MET | 73 | 0.7104 | 0.514 | 0.9818 | 0.4744 |

[4] Waller Test indicates Central system significantly lower than other two.

[5] Waller Test indicates Eastern System significantly higher than other two.

[6] Waller Test indicates a west-to-east gradient.

[7] Waller Test indicates Western System significantly higher than other two.

[8] Waller Test run but no significant differences found.

APPENDIX A. -- Continued.

******* LOCMOD.SAS Results Sorted by LOCxSYST ********

| | VARIABLE | FIGURE# | (Pr>F) LOCMODEL | (Pr>F) LOCATION | (Pr>F) SYSTEM | (Pr>F) LOCxSYST |
|---|---|---|---|---|---|---|
| | SED_DPTH | 15 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | DPTH_AVG | 12 | 0.0001 | 0.177 | 0.0935 | 0.0001 |
| | THALASSI | . | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | HALODULE | . | 0.0001 | 0.0001 | 0.0774 | 0.0001 |
| | PENICILLU | . | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | PLNT_TOT | 58 | 0.0001 | 0.0001 | 0.0107 | 0.0006 |
| | DO_PCT_L | 36 | 0.0001 | 0.0001 | 0.0273 | 0.0055 |
| >99% | MOLLUSKS | 68 | 0.0001 | 0.0001 | 0.2142 | 0.0073 |
| >95% | UDOTEA | | 0.026 | 0.1899 | 0.1067 | 0.0394 |
| | NEMERTEA | . | 0.0028 | 0.001 | 0.1158 | 0.1235 |
| | ECHINODE | . | 0.0157 | 0.0112 | 0.127 | 0.1448 |
| | LAURENCIA | . | 0.14 | 0.2944 | 0.2085 | 0.1517 |
| >80% | DPCORE_F | 64 | 0.0061 | 0.0094 | 0.0273 | 0.1613 |
| | VERTEBRA | . | 0.3106 | 0.0016 | 0.9671 | 0.2073 |
| | BATOPHOR | . | 0.1191 | 0.3615 | 0.0626 | 0.2178 |
| | LDMET_M2 | 71 | 0.0174 | 0.0681 | 0.0117 | 0.2216 |
| | EARLY_DO | 33 | 0.298 | 0.5456 | 0.2376 | 0.2397 |
| | LYNGBYA | . | 0.2484 | 0.3751 | 0.248 | 0.2416 |
| | REL_HUM | . | 0.1867 | 0.1762 | 0.3027 | 0.2517 |
| | OWMETAVG | 69 | 0.0001 | 0.0001 | 0.0075 | 0.26 |
| | CHAETOGN | . | 0.3408 | 0.3175 | 0.3715 | 0.333 |
| | ACETABUL | . | 0.3858 | 0.4592 | 0.3156 | 0.3341 |
| | NP_RATIO | 56 | 0.187 | 0.1238 | 0.2489 | 0.3645 |
| | SHCORE_F | . | 0.0001 | 0.0001 | 0.7912 | 0.371 |
| | HALIMEDA | . | 0.0001 | 0.0001 | 0.3419 | 0.3725 |
| | CNIDARIA | . | 0.1865 | 0.0833 | 0.3562 | 0.3761 |
| | CLADOPHO | . | 0.615 | 0.5966 | 0.492 | 0.4507 |
| | POLYSIPH | . | 0.4885 | 0.6391 | 0.1864 | 0.4734 |
| | DOME_MET | 73 | 0.7104 | 0.514 | 0.9818 | 0.4744 |
| | RHIZOCLO | . | 0.5815 | 0.5714 | 0.3831 | 0.4803 |
| >50% | RUPPIA | . | 0.5003 | 0.5366 | 0.2451 | 0.4961 |
| | PH | 10 | 0.3153 | 0.1009 | 0.4962 | 0.5341 |
| | TOTAL_N | 54 | 0.2328 | 0.0989 | 0.2374 | 0.5477 |
| | ANNELIDS | 68 | 0.1804 | 0.1047 | 0.1179 | 0.5528 |
| | CHARA | . | 0.3717 | 0.2819 | 0.2047 | 0.5727 |
| | DPTH_CHN | 14 | 0.2888 | 0.5127 | 0.0447 | 0.595 |
| | BOD_SRF | 46 | 0.4886 | 0.8851 | 0.0748 | 0.6071 |
| | SED_ORG | 17 | 0.6553 | 0.3216 | 0.7986 | 0.6229 |
| | SIPUNCUL | . | 0.002 | 0.0001 | 0.1521 | 0.6389 |
| | LTEXCOEF | 25 | 0.938 | 0.9373 | 0.9508 | 0.6503 |
| | SARGASSU | . | 0.6407 | 0.5664 | 0.2261 | 0.7122 |
| | ORTH_PO4 | 48 | 0.9523 | 0.9822 | 0.6924 | 0.7421 |
| | ARTHROPO | 68 | 0.004 | 0.0001 | 0.7982 | 0.7615 |
| | FAUN_TOT | 61 | 0.0012 | 0.0001 | 0.2683 | 0.7961 |
| | EPINET_F | . | 0.0038 | 0.0001 | 0.249 | 0.8048 |
| | SOMSTRAT | 32 | 0.7912 | 0.9577 | 0.1779 | 0.8314 |
| | TOTAL_P | 50 | 0.9018 | 0.4485 | 0.9705 | 0.8412 |
| | SAL_BOT | 4 | 0.0001 | 0.0001 | 0.0001 | 0.8458 |
| | SAL_SRF | 2 | 0.0001 | 0.0001 | 0.0002 | 0.8508 |
| | DO_CHNG | 34 | 0.2669 | 0.0454 | 0.2364 | 0.8707 |
| | DOME_FAU | 63 | 0.1974 | 0.0121 | 0.534 | 0.8893 |
| | AIR_TMP | . | 0.973 | 0.7529 | 0.7682 | 0.9139 |
| | NH4 | 52 | 0.6885 | 0.3819 | 0.202 | 0.9272 |
| | LT_SRF | . | 0.3736 | 0.1538 | 0.0888 | 0.9456 |
| | TSSSTRAT | 29 | 0.7193 | 0.6626 | 0.1169 | 0.9626 |
| | TSS_SRF | 27 | 0.7956 | 0.1919 | 0.7175 | 0.9635 |
| | WNDSPD | 21 | 0.9155 | 0.9326 | 0.1711 | 0.9798 |
| | WTMP_BOT | 8 | 0.9982 | 0.8157 | 0.8411 | 0.9933 |
| | WTMP_SRF | 6 | 0.9999 | 0.9731 | 0.8896 | 0.9958 |
| | SOM_SRF | 30 | 0.9873 | 0.6567 | 0.5177 | 0.9999 |

APPENDIX A. -- Continued.

*** DATEMOD.SAS Results Sorted by DATE ****

| | VARIABLE | FIGURE# | (Pr>F) DATEMODL | (Pr>F) DATE | (Pr>F) LOCxDATE |
|---|---|---|---|---|---|
| | TOTAL_N | 55 | 0.0002 | 0.0001 | 0.1219 |
| | TSS_SRF | 28 | 0.0002 | 0.0001 | 0.0567 |
| | NH4 | 53 | 0.0699 | 0.0001 | 0.9161 |
| | TSSSTRAT | . | 0.0001 | 0.0001 | 0.071 |
| | PH | 11 | 0.0003 | 0.0001 | 0.1613 |
| | SOM_SRF | 31 | 0.0001 | 0.0001 | 0.0001 |
| | WTMP_SRF | 7 | 0.0001 | 0.0001 | 0.5232 |
| | SOMSTRAT | . | 0.0001 | 0.0001 | 0.0001 |
| | WTMP_BOT | 9 | 0.0001 | 0.0001 | 0.7537 |
| | SAL_BOT | 5 | 0.0001 | 0.0001 | 0.0001 |
| | TOTAL_P | 51 | 0.0001 | 0.0001 | 0.2857 |
| | AIR_TMP | 22 | 0.0001 | 0.0001 | 0.7752 |
| | DOME_FAU | . | 0.0001 | 0.0001 | 0.0001 |
| | EARLY_DO | . | 0.0001 | 0.0001 | 0.8952 |
| | SAL_SRF | 3 | 0.0001 | 0.0001 | 0.0001 |
| | HALIMEDA | . | 0.0001 | 0.0001 | 0.0001 |
| | ORTH_PO4 | 49 | 0.0001 | 0.0001 | 0.6738 |
| | NP_RATIO | 57 | 0.0001 | 0.0001 | 0.0029 |
| | WNDSPD | 20 | 0.1371 | 0.0006 | 0.9734 |
| | DO_CHNG | 35 | 0.0263 | 0.0007 | 0.416 |
| | LT_SRF | 24 | 0.0527 | 0.001 | 0.6621 |
| | DOME_MET | 74 | 0.086 | 0.0019 | 0.6737 |
| | DPCORE_F | . | 0.0504 | 0.0049 | 0.3234 |
| >99% | SHCORE_F | . | 0.0001 | 0.0074 | 0.0001 |
| >95% | DPTH_AVG | 13 | 0.3062 | 0.0119 | 0.8682 |
| | CHARA | . | 0.0002 | 0.0541 | 0.0001 |
| >90% | BOD_SRF | 47 | 0.2525 | 0.0752 | 0.477 |
| | DO_PCT_L | 37 | 0.0099 | 0.1075 | 0.0112 |
| | REL_HUM | 23 | 0.7093 | 0.1081 | 0.9554 |
| | OWMETAVG | 70 | 0.0485 | 0.1124 | 0.068 |
| | BATOPHOR | | 0.338 | 0.1459 | 0.5022 |
| | SIPUNCUL | . | 0.0201 | 0.1833 | 0.0182 |
| >80% | FAUN_TOT | 65 | 0.0106 | 0.1978 | 0.0083 |
| | ECHINODE | . | 0.0113 | 0.2134 | 0.0086 |
| | EPINET_F | . | 0.0231 | 0.2298 | 0.0188 |
| | SARGASSU | . | 0.0374 | 0.2846 | 0.0293 |
| | DPTH_CHN | . | 0.726 | 0.3339 | 0.8277 |
| | CNIDARIA | . | 0.2528 | 0.3569 | 0.2413 |
| | THALASSI | . | 0.0001 | 0.3784 | 0.0001 |
| | ANNELIDS | 66 | 0.3349 | 0.3857 | 0.3236 |
| | LDMET_M2 | 72 | 0.6569 | 0.4246 | 0.6876 |
| | ARTHROPO | 66 | 0.0494 | 0.4438 | 0.0307 |
| >50% | ACETABUL | . | 0.6117 | 0.4728 | 0.6186 |
| | CHAETOGN | . | 0.5476 | 0.5202 | 0.509 |
| | RUPPIA | . | 0.4791 | 0.5327 | 0.4345 |
| | LAURENCIA | . | 0.6404 | 0.5425 | 0.6195 |
| | LYNGBYA | . | 0.6421 | 0.5467 | 0.6196 |
| | CLADOPHO | . | 0.6423 | 0.5479 | 0.6192 |
| | POLYSIPH | . | 0.6447 | 0.5697 | 0.612 |
| | NEMERTEA | . | 0.4018 | 0.5882 | 0.3244 |
| | UDOTEA | . | 0.6589 | 0.5905 | 0.6196 |
| | LTEXCOEF | 26 | 0.4341 | 0.5971 | 0.3554 |
| | RHIZOCLO | . | 0.9965 | 0.6057 | 0.9779 |
| | MOLLUSKS | 66 | 0.2085 | 0.6691 | 0.1313 |
| | PLNT_TOT | 59 | 0.0377 | 0.697 | 0.014 |
| | VERTEBRA | . | 0.1332 | 0.7356 | 0.0704 |
| | HALODULE | . | 0.0001 | 0.7952 | 0.0001 |
| | PENICILLU | . | 0.3946 | 0.9836 | 0.1709 |

APPENDIX A. -- Continued.

** DATEMOD.SAS Results Sorted by LOCxDATE **

| | VARIABLE | FIGURE# | (Pr>F) DATEMODL | (Pr>F) DATE | (Pr>F) LOCxDATE |
|---|---|---|---|---|---|
| | SAL_BOT | 5 | 0.0001 | 0.0001 | 0.0001 |
| | DOME_FAU | . | 0.0001 | 0.0001 | 0.0001 |
| | HALIMEDA | . | 0.0001 | 0.0001 | 0.0001 |
| | CHARA | . | 0.0002 | 0.0541 | 0.0001 |
| | HALODULE | . | 0.0001 | 0.7952 | 0.0001 |
| | SOMSTRAT | . | 0.0001 | 0.0001 | 0.0001 |
| | SOM_SRF | 31 | 0.0001 | 0.0001 | 0.0001 |
| | SHCORE_F | . | 0.0001 | 0.0074 | 0.0001 |
| | THALASSI | . | 0.0001 | 0.3784 | 0.0001 |
| | SAL_SRF | 3 | 0.0001 | 0.0001 | 0.0001 |
| | NP_RATIO | 57 | 0.0001 | 0.0001 | 0.0029 |
| | FAUN_TOT | 65 | 0.0106 | 0.1978 | 0.0083 |
| >99% | ECHINODE | . | 0.0113 | 0.2134 | 0.0086 |
| | DO_PCT_L | 37 | 0.0099 | 0.1075 | 0.0112 |
| | PLNT_TOT | 59 | 0.0377 | 0.697 | 0.014 |
| | SIPUNCUL | . | 0.0201 | 0.1833 | 0.0182 |
| | EPINET_F | . | 0.0231 | 0.2298 | 0.0188 |
| | SARGASSU | . | 0.0374 | 0.2846 | 0.0293 |
| >95% | ARTHROPO | 66 | 0.0494 | 0.4438 | 0.0307 |
| | TSS_SRF | 28 | 0.0002 | 0.0001 | 0.0567 |
| | OWMETAVG | 70 | 0.0485 | 0.1124 | 0.068 |
| | VERTEBRA | . | 0.1332 | 0.7356 | 0.0704 |
| >90% | TSSSTRAT | . | 0.0001 | 0.0001 | 0.071 |
| | TOTAL_N | 55 | 0.0002 | 0.0001 | 0.1219 |
| | MOLLUSKS | 66 | 0.2085 | 0.6691 | 0.1313 |
| | PH | 11 | 0.0003 | 0.0001 | 0.1613 |
| >80% | PENICILLU | . | 0.3946 | 0.9836 | 0.1709 |
| | CNIDARIA | . | 0.2528 | 0.3569 | 0.2413 |
| | TOTAL_P | 51 | 0.0001 | 0.0001 | 0.2857 |
| | DPCORE_F | . | 0.0504 | 0.0049 | 0.3234 |
| | ANNELIDS | 66 | 0.3349 | 0.3857 | 0.3236 |
| | NEMERTEA | . | 0.4018 | 0.5882 | 0.3244 |
| | LTEXCOEF | 26 | 0.4341 | 0.5971 | 0.3554 |
| | DO_CHNG | 35 | 0.0263 | 0.0007 | 0.416 |
| | RUPPIA | . | 0.4791 | 0.5327 | 0.4345 |
| >50% | BOD_SRF | 47 | 0.2525 | 0.0752 | 0.477 |
| | BATOPHOR | . | 0.338 | 0.1459 | 0.5022 |
| | CHAETOGN | . | 0.5476 | 0.5202 | 0.509 |
| | WTMP_SRF | 7 | 0.0001 | 0.0001 | 0.5232 |
| | POLYSIPH | . | 0.6447 | 0.5697 | 0.612 |
| | ACETABUL | . | 0.6117 | 0.4728 | 0.6186 |
| | CLADOPHO | . | 0.6423 | 0.5479 | 0.6192 |
| | LAURENCIA | . | 0.6404 | 0.5425 | 0.6195 |
| | LYNGBYA | . | 0.6421 | 0.5467 | 0.6196 |
| | UDOTEA | . | 0.6589 | 0.5905 | 0.6196 |
| | LT_SRF | 24 | 0.0527 | 0.001 | 0.6621 |
| | DOME_MET | 74 | 0.086 | 0.0019 | 0.6737 |
| | ORTH_PO4 | 49 | 0.0001 | 0.0001 | 0.6738 |
| | LDMET_M2 | 72 | 0.6569 | 0.4246 | 0.6876 |
| | WTMP_BOT | 9 | 0.0001 | 0.0001 | 0.7537 |
| | AIR_TMP | 22 | 0.0001 | 0.0001 | 0.7752 |
| | DPTH_CHN | . | 0.726 | 0.3339 | 0.8277 |
| | DPTH_AVG | 13 | 0.3062 | 0.0119 | 0.8682 |
| | EARLY_DO | . | 0.0001 | 0.0001 | 0.8952 |
| | NH4 | 53 | 0.0699 | 0.0001 | 0.9161 |
| | REL_HUM | 23 | 0.7093 | 0.1081 | 0.9554 |
| | WNDSPD | 20 | 0.1371 | 0.0006 | 0.9734 |
| | RHIZOCLO | . | 0.9965 | 0.6057 | 0.9779 |



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APPENDIX B. Results of SAS Regression Analyses of the 12 Station Means and Standard Deviations of each measured variable vs location.

| OBS | _DEPVAR_ | _RMSE_ | INTERCEP | LOCATION | _RSQ_ | |
|---|---|---|---|---|---|---|
| 1 | LOGMFAUN | 0.65 | 11.15 | -1.41 | 0.87772 | |
| 2 | LOGMNOLY | 1.13 | 8.33 | -1.84 | 0.79948 | |
| 3 | MFAUN | 4081.00 | 20230.89 | -5598.97 | 0.73845 | |
| 4 | MSALSRF | 4.26 | 35.12 | -5.40 | 0.70729 | |
| 5 | LOGMPLNT | 1.35 | 7.92 | -1.59 | 0.67452 | |
| 6 | MDOPCTL | 9.29 | 123.48 | -10.37 | 0.65129 | |
| 7 | MSALBOT | 4.70 | 35.73 | -5.07 | 0.63585 | |
| 8 | SSALBOT | 1.40 | 5.82 | 1.45 | 0.61918 | |
| 9 | MOWMETAV | 66.42 | 281.82 | -66.12 | 0.59786 | |
| 10 | SFAUN | 5713.51 | 19474.05 | -5486.67 | 0.58041 | |
| 11 | MDOCHNG | 0.05 | 0.32 | -0.04 | 0.53171 | |
| 12 | MNOLYNG | 269.52 | 847.24 | -233.10 | 0.52874 | |
| 13 | MPLNT | 270.83 | 841.44 | -229.62 | 0.51881 | >99% |
| 14 | MTOTALP | 2.64 | 10.38 | 2.08 | 0.48095 | |
| 15 | SSALSRF | 1.83 | 6.07 | 1.42 | 0.47411 | |
| 16 | MTSSSRF | 2.92 | 16.80 | -1.98 | 0.40864 | |
| 17 | STOTALN | 169.79 | 84.62 | 112.17 | 0.39565 | |
| 18 | MTOTALN | 134.15 | 1116.03 | 84.29 | 0.37195 | |
| 19 | SNH4 | 20.95 | 37.99 | 12.87 | 0.36167 | |
| 20 | MWTMPBOT | 0.35 | 27.89 | 0.21 | 0.35213 | >95% |
| 21 | MNH4 | 18.62 | 71.17 | 10.40 | 0.31877 | |
| 22 | SLTEXCOF | 0.44 | 1.29 | -0.24 | 0.31259 | |
| 23 | MSOMSRF | 0.85 | 5.64 | -0.46 | 0.30675 | >90% |
| 24 | SDOCHNG | 0.07 | 0.22 | -0.03 | 0.24710 | |
| 25 | MLDMETM2 | 16.02 | 6.74 | 7.34 | 0.23947 | |
| 26 | SLDMETM2 | 16.73 | 5.92 | 7.63 | 0.23808 | |
| 27 | SDOMEMET | 10.26 | 42.52 | -4.54 | 0.22676 | |
| 28 | * SEDSHELL | 4.20 | 11.81 | -1.74 | 0.21892 | |
| 29 | MPH | 0.13 | 8.24 | -0.06 | 0.21086 | |
| 30 | MNPRATIO | 91.05 | 405.75 | -37.00 | 0.19851 | |
| 31 | MDOMEMET | 10.37 | 42.38 | -4.03 | 0.18467 | |
| 32 | SOWMETAV | 64.10 | 169.58 | -23.35 | 0.16601 | >80% |
| 33 | MDPTHCHN | 1.71 | 4.71 | -0.57 | 0.14416 | |
| 34 | STSSSRF | 3.83 | 14.51 | -1.28 | 0.14366 | |
| 35 | MSEDORG | 2.97 | 6.82 | 0.99 | 0.14318 | |
| 36 | SSOMBOT | 3.12 | 3.16 | 1.03 | 0.14196 | |
| 37 | STOTALP | 6.52 | 8.24 | 2.16 | 0.14105 | |
| 38 | * SEDMOIST | 11.45 | 53.40 | 3.56 | 0.13681 | |
| 39 | SDPTHCHN | 1.74 | 5.18 | -0.57 | 0.13665 | |
| 40 | MWTMPSRF | 0.37 | 27.50 | 0.12 | 0.13042 | |
| 41 | MSEDDPTH | 24.80 | 98.48 | -7.52 | 0.12126 | |
| 42 | SNOLYNG | 346.99 | 423.97 | -103.79 | 0.11832 | |
| 43 | SPO4TP | 17.95 | 22.55 | 5.25 | 0.11357 | |
| 44 | SPLNT | 347.53 | 411.44 | -96.27 | 0.10323 | |
| 45 | SNPRATIO | 129.89 | 296.45 | -35.65 | 0.10154 | |
| 46 | SBODBOT | 0.19 | 0.50 | -0.05 | 0.09640 | |
| 47 | MTSSBOT | 3.99 | 16.71 | -1.06 | 0.09489 | |
| 48 | MEARLYDO | 0.64 | 5.75 | -0.16 | 0.08772 | |
| 49 | SWNDSPD | 0.38 | 0.90 | 0.09 | 0.08177 | |



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APPENDIX B. -- Continued.

| OBS | | _DEPVAR_ | _RMSE_ | INTERCEP | LOCATION | _RSQ_ | |
|---|---|---|---|---|---|---|---|
| 50 | | STSSBOT | 3.63 | 13.67 | -0.86 | 0.07725 | |
| 51 | | MPO4TP | 9.22 | 22.69 | 1.95 | 0.06272 | |
| 52 | | SSEDDPTH | 2.90 | 5.23 | -0.61 | 0.06157 | |
| 53 | | MWNDSPD | 0.32 | 2.52 | 0.07 | 0.06097 | |
| 54 | | SORTHPO4 | 0.78 | 2.16 | 0.15 | 0.05320 | >50% |
| 55 | * | SEDSILT | 12.10 | 38.64 | 2.19 | 0.05079 | |
| 56 | | MORTHPO4 | 0.59 | 2.18 | 0.10 | 0.03984 | |
| 57 | | MBODSRF | 0.2863 | 0.9067 | 0.03947 | 0.027713 | |
| 58 | | MDPTHAVG | 11.3393 | 84.2604 | -1.47500 | 0.024752 | |
| 59 | | AORGMAT | 9.2144 | 13.5852 | -0.63704 | 0.007761 | |
| 60 | * | SBODSRF | 0.4251 | 0.6368 | -0.02644 | 0.005768 | |
| 61 | | SSOMSRF | 1.4298 | 4.7996 | -0.08872 | 0.005742 | |
| 62 | | SWTMPBOT | 0.5647 | 3.8635 | -0.03347 | 0.005242 | |
| 63 | | MBODBOT | 0.2640 | 0.8521 | 0.01559 | 0.005200 | |
| 64 | | SSEDORG | 3.4367 | 3.2458 | -0.15072 | 0.002877 | |
| 65 | | SDPTHAVG | 3.3936 | 11.2915 | 0.14818 | 0.002852 | |
| 66 | | MLTEXCOF | 0.2144 | 1.1604 | 0.00931 | 0.002819 | |
| 67 | | SPH | 0.1353 | 0.3306 | -0.00570 | 0.002652 | |
| 68 | * | SEDSAND | 7.2575 | 13.4869 | -0.25770 | 0.002059 | |
| 69 | | MSOMBOT | 2.2299 | 5.4665 | 0.08143 | 0.001996 | |
| 70 | * | SEDSOLUB | 3.2928 | 96.9000 | -0.10000 | 0.001507 | |
| 71 | | SDOPCTL | 6.9343 | 12.7710 | 0.16368 | 0.000835 | |
| 72 | | SEARLYDO | 0.4111 | 1.4762 | 0.00926 | 0.000761 | |
| 73 | * | SEDCLAY | 11.9113 | 36.0578 | -0.18974 | 0.000415 | |
| 74 | | SWTMPSRF | 0.3289 | 4.1354 | 0.00460 | 0.000294 | |
| 75 | * | AORG_LT2 | 6.2844 | 9.3152 | 0.04796 | 0.000095 | |

* Only 11 stations in regression.



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APPENDIX C. SAS Correlations of Plant, Fauna, and Metabolism Variables to All Other Measured Variables.

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 1 | 1 | MEAN | | 30.0625 | 29.7542 | 27.9375 | 27.8896 |
| 2 | 1 | STD | | 8.7444 | 8.7702 | 4.3295 | 4.3070 |
| 3 | 1 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 4 | 1 | CORR | LYNGBYA | . | . | . | . |
| 5 | 1 | CORR | SARGASSU | 0.0262 | 0.0337 | 0.0013 | -0.0091 |
| 6 | 1 | CORR | ACETABUL | 0.2280 | 0.2345 | 0.1358 | 0.1636 |
| 7 | 1 | CORR | BATOPHOR | 0.2766 | 0.2574 | -0.0281 | -0.0514 |
| 8 | 1 | CORR | CHARA | -0.1744 | -0.1689 | -0.4962 | -0.5064 |
| 9 | 1 | CORR | CLADOPHO | -0.0040 | 0.0035 | 0.0178 | 0.0203 |
| 10 | 1 | CORR | HALIMEDA | . | . | . | . |
| 11 | 1 | CORR | PENICILL | -0.3307 | -0.3145 | -0.0245 | -0.0182 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 1 | 4.3810 | 85.2083 | 2.5969 | 1.0980 | 1509.00 | 12.7789 | 3.2900 |
| 2 | 5.2581 | 18.2316 | 0.9716 | 1.1920 | 542.50 | 10.6297 | 2.9104 |
| 3 | 21.0000 | 24.0000 | 21.0000 | 19.0000 | 20.00 | 19.0000 | 5.0000 |
| 4 | . | . | . | . | . | . | . |
| 5 | 0.0005 | -0.1968 | 0.0228 | -0.0560 | 0.16 | -0.1134 | . |
| 6 | -0.1482 | 0.0989 | 0.0226 | -0.1520 | 0.20 | 0.4402 | -0.2094 |
| 7 | -0.1948 | -0.0109 | -0.0352 | -0.3136 | 0.05 | 0.6986 | -0.1976 |
| 8 | -0.0606 | 0.2145 | 0.1236 | -0.1317 | -0.16 | 0.2146 | -0.2094 |
| 9 | -0.1909 | 0.1728 | 0.0201 | -0.0890 | 0.10 | -0.1544 | . |
| 10 | . | . | . | . | . | . | . |
| 11 | -0.0584 | 0.5687 | 0.2529 | -0.0006 | -0.33 | -0.1150 | 0.9408 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 1 | 4.9158 | 1.5200 | 111.948 | 5.4274 | 0.3018 | 0.9916 | 2.3196 |
| 2 | 5.0541 | 2.2070 | 18.297 | 1.5853 | 0.2251 | 0.7954 | 2.3263 |
| 3 | 19.0000 | 5.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 4 | . | . | . | . | . | . | . |
| 5 | -0.1547 | . | -0.066 | 0.0642 | -0.1666 | 0.0552 | 0.0192 |
| 6 | 0.2704 | -0.1570 | 0.135 | -0.1064 | 0.0277 | -0.1046 | -0.0359 |
| 7 | 0.6007 | -0.1552 | -0.027 | -0.0845 | -0.0676 | -0.1576 | 0.2702 |
| 8 | 0.5550 | -0.1570 | 0.128 | 0.4317 | 0.1051 | 0.0172 | 0.1601 |
| 9 | -0.0127 | . | -0.027 | -0.0295 | -0.0056 | -0.0681 | -0.2174 |
| 10 | . | . | . | . | . | . | . |
| 11 | -0.1402 | 0.3567 | -0.197 | -0.0016 | 0.0287 | 0.1198 | -0.0160 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 1 | 13.6583 | 89.413 | 1253.91 | 332.355 | 20.6451 | 8.1142 |
| 2 | 10.9874 | 55.759 | 221.21 | 289.304 | 22.6417 | 0.3993 |
| 3 | 24.0000 | 23.000 | 23.00 | 23.000 | 23.0000 | 19.0000 |
| 4 | . | . | . | . | . | . |
| 5 | -0.0858 | -0.119 | 0.01 | -0.040 | 0.0559 | -0.6565 |
| 6 | -0.0186 | 0.046 | 0.12 | -0.073 | -0.0577 | 0.5708 |
| 7 | -0.0093 | 0.332 | 0.51 | -0.141 | 0.1046 | 0.2086 |
| 8 | -0.1094 | -0.046 | -0.30 | -0.053 | 0.2840 | -0.1666 |
| 9 | -0.2260 | . | 0.06 | 0.842 | -0.1988 | -0.0450 |
| 10 | . | . | . | . | . | . |
| 11 | -0.0736 | -0.316 | -0.08 | 0.435 | -0.1033 | 0.0398 |

APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 12 | 1 | CORR | RHIZOCLO | . | . | . | . |
| 13 | 1 | CORR | UDOTEA | 0.0642 | 0.0643 | -0.0240 | -0.0168 |
| 14 | 1 | CORR | LAURENCI | 0.0286 | 0.0362 | 0.0385 | 0.0269 |
| 15 | 1 | CORR | LAUR_POL | 0.0049 | 0.0029 | 0.0882 | 0.0722 |
| 16 | 1 | CORR | POLYSIPH | 0.2273 | 0.2247 | 0.2104 | 0.1693 |
| 17 | 1 | CORR | HALODULE | -0.0538 | -0.0299 | 0.3097 | 0.3154 |
| 18 | 1 | CORR | RUPPIA | -0.5407 | -0.5312 | 0.1217 | 0.1325 |
| 19 | 1 | CORR | RUP_HALO | -0.1118 | -0.1156 | -0.1534 | -0.1637 |
| 20 | 1 | CORR | THALASSI | 0.2177 | 0.2073 | 0.0049 | -0.0228 |
| 21 | 1 | CORR | PLNT_TOT | 0.0160 | 0.0185 | -0.0461 | -0.0812 |
| 22 | 1 | CORR | NOLYNG | 0.0160 | 0.0185 | -0.0461 | -0.0812 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 12 | . | . | . | . | . | . | . |
| 13 | -0.0166 | 0.0443 | 0.1255 | -0.1441 | 0.21 | -0.2319 | . |
| 14 | 0.0234 | -0.1461 | 0.0207 | -0.0402 | 0.17 | -0.0686 | -0.3039 |
| 15 | 0.0287 | 0.0049 | 0.0411 | -0.0389 | 0.17 | -0.0793 | . |
| 16 | -0.1460 | -0.0948 | 0.2878 | -0.2740 | 0.09 | 0.4382 | . |
| 17 | 0.0504 | 0.1928 | -0.2362 | -0.1822 | -0.30 | 0.1877 | 0.6182 |
| 18 | -0.1257 | 0.1821 | 0.5681 | 0.0459 | -0.44 | -0.1071 | . |
| 19 | 0.2413 | 0.0163 | 0.2565 | 0.2574 | -0.12 | 0.1278 | . |
| 20 | -0.0716 | -0.5717 | 0.0759 | 0.0338 | 0.30 | -0.0126 | -0.9141 |
| 21 | -0.1572 | -0.2935 | 0.3552 | 0.0268 | 0.18 | -0.0972 | -0.7667 |
| 22 | -0.1572 | -0.2935 | 0.3552 | 0.0268 | 0.18 | -0.0972 | -0.7667 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 12 | . | . | . | . | . | . | . |
| 13 | -0.1469 | . | -0.140 | -0.0719 | -0.0162 | -0.0472 | -0.2174 |
| 14 | -0.1189 | 0.2261 | -0.069 | 0.0032 | -0.1069 | 0.0749 | 0.0159 |
| 15 | -0.1253 | . | -0.023 | 0.0110 | -0.0657 | 0.0880 | -0.1991 |
| 16 | 0.1987 | . | -0.084 | -0.3493 | 0.1585 | -0.0472 | -0.2980 |
| 17 | 0.0675 | 0.4540 | -0.209 | -0.4625 | 0.1802 | 0.2222 | -0.3183 |
| 18 | -0.0778 | . | -0.163 | 0.0531 | -0.0698 | 0.0546 | 0.4451 |
| 19 | -0.0928 | . | -0.070 | 0.2074 | -0.2187 | -0.1543 | 0.2666 |
| 20 | 0.0495 | -0.3411 | 0.548 | 0.1339 | 0.2782 | -0.0612 | 0.0967 |
| 21 | -0.0820 | -0.2771 | 0.574 | 0.2223 | 0.3862 | 0.0384 | 0.1341 |
| 22 | -0.0820 | -0.2771 | 0.574 | 0.2223 | 0.3862 | 0.0384 | 0.1341 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 12 | . | . | . | . | . | . |
| 13 | -0.1485 | -0.009 | -0.22 | 0.036 | -0.1988 | 0.1976 |
| 14 | -0.0714 | -0.118 | 0.05 | -0.035 | 0.0404 | -0.6381 |
| 15 | -0.2056 | -0.311 | 0.04 | 0.265 | -0.1674 | -0.1679 |
| 16 | -0.0888 | 0.100 | 0.14 | -0.045 | -0.2725 | 0.1976 |
| 17 | -0.1883 | -0.108 | -0.04 | 0.027 | -0.1990 | -0.0802 |
| 18 | 0.2039 | -0.167 | -0.03 | -0.179 | 0.1987 | 0.0838 |
| 19 | 0.0541 | -0.200 | -0.18 | -0.182 | 0.1080 | 0.2580 |
| 20 | -0.0341 | 0.161 | 0.15 | -0.105 | 0.2955 | -0.2958 |
| 21 | -0.1507 | -0.066 | 0.12 | 0.211 | 0.3469 | -0.4771 |
| 22 | -0.1507 | -0.066 | 0.12 | 0.211 | 0.3469 | -0.4771 |

APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 23 | 2 | MEAN | | 25.9417 | 24.0375 | 28.0250 | 28.1292 |
| 24 | 2 | STD | | 10.0245 | 11.0020 | 4.1894 | 4.0934 |
| 25 | 2 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 26 | 2 | CORR | LYNGBYA | . | . | . | . |
| 27 | 2 | CORR | SARGASSU | -0.0866 | -0.2688 | 0.1112 | 0.1133 |
| 28 | 2 | CORR | ACETABUL | 0.3013 | 0.3110 | 0.1436 | 0.1411 |
| 29 | 2 | CORR | BATOPHOR | 0.2958 | 0.3072 | 0.1331 | 0.1328 |
| 30 | 2 | CORR | CHARA | . | . | . | . |
| 31 | 2 | CORR | CLADOPHO | 0.0331 | 0.0670 | -0.0140 | -0.0197 |
| 32 | 2 | CORR | HALIMEDA | 0.2945 | 0.3052 | 0.1258 | 0.1234 |
| 33 | 2 | CORR | PENICILL | 0.3081 | 0.3213 | 0.1274 | 0.1250 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 23 | 3.1000 | 78.2500 | 2.6011 | 1.2346 | 1538.00 | 15.3275 | 3.7250 |
| 24 | 4.5757 | 13.1033 | 1.0862 | 0.7652 | 594.97 | 15.5188 | 5.2219 |
| 25 | 20.0000 | 24.0000 | 21.0000 | 20.0000 | 20.00 | 20.0000 | 6.0000 |
| 26 | . | . | . | . | . | . | . |
| 27 | 0.0261 | -0.2815 | -0.1182 | 0.0667 | 0.17 | 0.0082 | -0.2087 |
| 28 | 0.4486 | 0.0077 | 0.4987 | 0.1661 | 0.19 | 0.5071 | 0.8795 |
| 29 | 0.4632 | 0.0073 | 0.4784 | 0.1663 | 0.17 | 0.4992 | -0.4339 |
| 30 | . | . | . | . | . | . | . |
| 31 | -0.1595 | 0.1910 | 0.1114 | -0.0957 | 0.08 | -0.1172 | . |
| 32 | 0.4578 | -0.0041 | 0.4885 | 0.1738 | 0.20 | 0.5046 | . |
| 33 | 0.4506 | -0.0066 | 0.4953 | 0.1465 | 0.22 | 0.4842 | 0.8795 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 23 | 4.8025 | 2.6167 | 104.249 | 5.5758 | 0.2159 | 0.9455 | 2.3043 |
| 24 | 3.4793 | 4.4388 | 12.174 | 1.3219 | 0.1342 | 0.4783 | 2.7620 |
| 25 | 20.0000 | 6.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 26 | . | . | . | . | . | . | . |
| 27 | -0.0824 | -0.1453 | 0.192 | -0.1664 | 0.3172 | 0.0941 | 0.0497 |
| 28 | 0.4268 | 0.7652 | 0.319 | -0.3133 | 0.5106 | -0.1064 | -0.1289 |
| 29 | 0.4221 | -0.3109 | 0.314 | -0.3071 | 0.5102 | 0.0299 | -0.1892 |
| 30 | . | . | . | . | . | . | . |
| 31 | 0.0607 | . | -0.335 | -0.0806 | -0.1278 | 0.0727 | -0.1819 |
| 32 | 0.4328 | . | 0.319 | -0.2997 | 0.5074 | . | -0.1819 |
| 33 | 0.4234 | 0.7652 | 0.351 | -0.3110 | 0.5460 | -0.1071 | -0.1966 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 23 | 15.1917 | 106.045 | 1238.96 | 269.057 | 21.9233 | 8.3021 |
| 24 | 10.9274 | 71.446 | 275.29 | 148.583 | 27.8158 | 0.4324 |
| 25 | 24.0000 | 22.000 | 24.00 | 24.000 | 23.0000 | 17.0000 |
| 26 | . | . | . | . | . | . |
| 27 | -0.2293 | -0.095 | -0.40 | 0.165 | 0.4085 | 0.2389 |
| 28 | 0.0999 | 0.130 | 0.40 | -0.123 | -0.1509 | 0.4799 |
| 29 | 0.1199 | 0.093 | 0.37 | -0.127 | -0.1800 | 0.4398 |
| 30 | . | . | . | . | . | . |
| 31 | -0.1792 | 0.300 | -0.18 | 0.143 | -0.1718 | -0.1562 |
| 32 | 0.0937 | 0.097 | 0.37 | -0.113 | -0.1718 | 0.4398 |
| 33 | 0.0726 | 0.067 | 0.37 | -0.087 | -0.1815 | 0.4868 |



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APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 34 | 2 | CORR | RHIZOCLO | . | . | . | . |
| 35 | 2 | CORR | UDOTEA | 0.2502 | 0.2742 | 0.0758 | 0.0750 |
| 36 | 2 | CORR | LAURENCI | 0.5256 | 0.5479 | 0.2173 | 0.2131 |
| 37 | 2 | CORR | LAUR_POL | 0.1160 | 0.1367 | 0.0165 | 0.0167 |
| 38 | 2 | CORR | POLYSIPH | 0.4530 | 0.4503 | 0.2044 | 0.2037 |
| 39 | 2 | CORR | HALODULE | 0.2270 | 0.1875 | 0.1808 | 0.1638 |
| 40 | 2 | CORR | RUPPIA | -0.4146 | -0.4121 | 0.1200 | 0.1345 |
| 41 | 2 | CORR | RUP_HALO | -0.1413 | -0.1463 | 0.1060 | 0.0865 |
| 42 | 2 | CORR | THALASSI | 0.2152 | 0.2531 | 0.2469 | 0.2339 |
| 43 | 2 | CORR | PLNT_TOT | 0.3073 | 0.3369 | 0.1461 | 0.1416 |
| 44 | 2 | CORR | NOLYNG | 0.3073 | 0.3369 | 0.1461 | 0.1416 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 34 | . | . | . | . | . | . | . |
| 35 | 0.0838 | -0.0065 | 0.1970 | -0.1544 | 0.26 | -0.0032 | 0.8795 |
| 36 | 0.0473 | 0.1793 | -0.0341 | 0.0711 | 0.35 | 0.0208 | 0.8795 |
| 37 | -0.0566 | -0.0203 | 0.0642 | -0.2218 | 0.18 | -0.1627 | 0.8795 |
| 38 | -0.1520 | 0.1097 | -0.3096 | -0.0050 | 0.23 | -0.1319 | 0.8795 |
| 39 | -0.2887 | -0.3093 | -0.5067 | -0.2509 | -0.17 | -0.0057 | -0.1263 |
| 40 | 0.1308 | 0.2369 | 0.0085 | 0.0322 | 0.11 | -0.1431 | -0.1961 |
| 41 | -0.0793 | 0.1005 | 0.0618 | -0.0881 | 0.12 | -0.2779 | -0.2087 |
| 42 | -0.1578 | 0.3167 | -0.0882 | -0.0217 | 0.13 | -0.1552 | -0.5022 |
| 43 | 0.0485 | 0.0583 | 0.1688 | -0.1614 | 0.30 | -0.0268 | 0.8746 |
| 44 | 0.0485 | 0.0583 | 0.1688 | -0.1614 | 0.30 | -0.0268 | 0.8746 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 34 | . | . | . | . | . | . | . |
| 35 | 0.0486 | 0.7652 | 0.3989 | -0.2112 | 0.5074 | -0.1067 | -0.1888 |
| 36 | -0.1219 | 0.7652 | 0.5992 | -0.3200 | 0.6017 | 0.0183 | -0.2185 |
| 37 | -0.0712 | 0.7652 | 0.2649 | -0.0957 | 0.3214 | -0.1064 | -0.1227 |
| 38 | -0.2605 | 0.7652 | 0.3550 | -0.2180 | 0.2684 | -0.0337 | -0.1222 |
| 39 | 0.0743 | -0.1367 | 0.0928 | -0.2130 | 0.1232 | -0.0958 | 0.0202 |
| 40 | -0.2348 | -0.1342 | -0.4006 | -0.0793 | -0.1445 | 0.2114 | 0.0735 |
| 41 | -0.5039 | -0.1453 | 0.0109 | 0.0171 | 0.0298 | 0.1982 | 0.5038 |
| 42 | -0.2842 | -0.3559 | 0.4668 | -0.0977 | 0.3592 | 0.2695 | 0.0587 |
| 43 | -0.0038 | 0.7634 | 0.5086 | -0.2461 | 0.5985 | -0.0397 | -0.1725 |
| 44 | -0.0038 | 0.7634 | 0.5086 | -0.2461 | 0.5985 | -0.0397 | -0.1725 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 34 | . | . | . | . | . | . |
| 35 | -0.1127 | -0.207 | 0.12 | 0.148 | -0.1486 | 0.5132 |
| 36 | 0.1269 | -0.077 | 0.26 | -0.092 | -0.2328 | 0.5793 |
| 37 | -0.1694 | -0.241 | -0.01 | 0.210 | -0.0814 | 0.3802 |
| 38 | 0.2510 | -0.090 | 0.12 | -0.231 | -0.1526 | 0.4920 |
| 39 | -0.0869 | 0.558 | -0.11 | -0.127 | -0.1105 | 0.2758 |
| 40 | 0.0213 | -0.045 | 0.40 | -0.028 | -0.0213 | -0.0102 |
| 41 | -0.1723 | -0.262 | -0.00 | 0.151 | 0.5970 | -0.3969 |
| 42 | -0.0018 | -0.153 | 0.12 | 0.031 | 0.1210 | 0.0813 |
| 43 | -0.1143 | -0.221 | 0.15 | 0.148 | -0.1218 | 0.5371 |
| 44 | -0.1143 | -0.221 | 0.15 | 0.148 | -0.1218 | 0.5371 |

APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 45 | 3 | MEAN | | 18.4667 | 16.5792 | 27.8438 | 28.4275 |
| 46 | 3 | STD | | 12.0470 | 12.2420 | 3.9662 | 4.3545 |
| 47 | 3 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 48 | 3 | CORR | LYNGBYA | . | . | . | . |
| 49 | 3 | CORR | SARGASSU | . | . | . | . |
| 50 | 3 | CORR | ACETABUL | . | . | . | . |
| 51 | 3 | CORR | BATOPHOR | . | . | . | . |
| 52 | 3 | CORR | CHARA | -0.4695 | -0.4071 | 0.1494 | 0.0850 |
| 53 | 3 | CORR | CLADOPHO | . | . | . | . |
| 54 | 3 | CORR | HALIMEDA | . | . | . | . |
| 55 | 3 | CORR | PENICILL | 0.0802 | -0.0257 | 0.1158 | 0.2652 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 45 | 3.0000 | 78.6875 | 2.7565 | 1.2316 | 1183.89 | 11.8976 | 7.6050 |
| 46 | 3.1623 | 17.1634 | 1.2521 | 0.6212 | 481.64 | 9.8408 | 7.7415 |
| 47 | 19.0000 | 24.0000 | 21.0000 | 21.0000 | 18.00 | 21.0000 | 10.0000 |
| 48 | . | . | . | . | . | . | . |
| 49 | . | . | . | . | . | . | . |
| 50 | . | . | . | . | . | . | . |
| 51 | . | . | . | . | . | . | . |
| 52 | -0.3246 | -0.2512 | 0.2872 | -0.0169 | -0.27 | -0.1185 | -0.3270 |
| 53 | . | . | . | . | . | . | . |
| 54 | . | . | . | . | . | . | . |
| 55 | -0.0766 | -0.0334 | -0.2999 | -0.0367 | -0.41 | -0.0384 | 0.1450 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 45 | 4.8833 | 2.9950 | 92.8923 | 5.4464 | 0.1845 | 0.9692 | 2.4043 |
| 46 | 5.4227 | 3.2609 | 10.6234 | 1.5135 | 0.1060 | 0.5843 | 2.9925 |
| 47 | 21.0000 | 10.0000 | 21.0000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 48 | . | . | . | . | . | . | . |
| 49 | . | . | . | . | . | . | . |
| 50 | . | . | . | . | . | . | . |
| 51 | . | . | . | . | . | . | . |
| 52 | 0.1376 | -0.3648 | 0.0551 | 0.2405 | -0.2011 | 0.0131 | 0.0173 |
| 53 | . | . | . | . | . | . | . |
| 54 | . | . | . | . | . | . | . |
| 55 | -0.1366 | -0.1288 | -0.2108 | -0.2598 | 0.2949 | 0.0135 | -0.1096 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 45 | 17.9981 | 103.688 | 1355.63 | 262.507 | 26.9364 | 8.0333 |
| 46 | 20.0639 | 70.890 | 323.58 | 142.904 | 36.9810 | 0.3094 |
| 47 | 24.0000 | 24.000 | 24.00 | 24.000 | 23.0000 | 18.0000 |
| 48 | . | . | . | . | . | . |
| 49 | . | . | . | . | . | . |
| 50 | . | . | . | . | . | . |
| 51 | . | . | . | . | . | . |
| 52 | -0.2300 | -0.088 | -0.08 | 0.636 | 0.1528 | 0.0454 |
| 53 | . | . | . | . | . | . |
| 54 | . | . | . | . | . | . |
| 55 | 0.8812 | -0.014 | -0.07 | -0.351 | -0.1535 | 0.0054 |

APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 56 | 3 | CORR | RHIZOCLO | . | . | . | . |
| 57 | 3 | CORR | UDOTEA | . | . | . | . |
| 58 | 3 | CORR | LAURENCI | . | . | . | . |
| 59 | 3 | CORR | LAUR_POL | . | . | . | . |
| 60 | 3 | CORR | POLYSIPH | . | . | . | . |
| 61 | 3 | CORR | HALODULE | -0.1406 | -0.0792 | 0.0086 | -0.0015 |
| 62 | 3 | CORR | RUPPIA | 0.0465 | 0.0702 | 0.1288 | 0.1437 |
| 63 | 3 | CORR | RUP_HALO | -0.2425 | -0.2511 | 0.1564 | 0.2118 |
| 64 | 3 | CORR | THALASSI | 0.1438 | 0.1483 | 0.1239 | 0.1332 |
| 65 | 3 | CORR | PLNT_TOT | -0.4514 | -0.4157 | 0.2337 | 0.2438 |
| 66 | 3 | CORR | NOLYNG | -0.4514 | -0.4157 | 0.2337 | 0.2438 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 56 | . | . | . | . | . | . | . |
| 57 | . | . | . | . | . | . | . |
| 58 | . | . | . | . | . | . | . |
| 59 | . | . | . | . | . | . | . |
| 60 | . | . | . | . | . | . | . |
| 61 | -0.0253 | 0.7660 | 0.3527 | -0.0411 | -0.31 | -0.0645 | -0.0916 |
| 62 | -0.1717 | 0.0421 | -0.0414 | -0.1727 | 0.27 | -0.1836 | -0.3672 |
| 63 | -0.1003 | 0.0139 | 0.3865 | -0.1317 | -0.12 | -0.2070 | 0.8621 |
| 64 | -0.2297 | 0.0287 | -0.1159 | -0.1433 | 0.20 | 0.0920 | -0.3406 |
| 65 | -0.3090 | 0.0311 | 0.1786 | -0.1528 | -0.63 | -0.2271 | -0.1484 |
| 66 | -0.3090 | 0.0311 | 0.1786 | -0.1528 | -0.63 | -0.2271 | -0.1484 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 56 | . | . | . | . | . | . | . |
| 57 | . | . | . | . | . | . | . |
| 58 | . | . | . | . | . | . | . |
| 59 | . | . | . | . | . | . | . |
| 60 | . | . | . | . | . | . | . |
| 61 | 0.0077 | 0.2358 | -0.0087 | 0.0544 | -0.1270 | -0.3784 | -0.1818 |
| 62 | -0.1660 | -0.3773 | -0.6629 | -0.3808 | 0.0417 | -0.2182 | -0.0322 |
| 63 | -0.2067 | 0.0975 | 0.1503 | 0.1803 | -0.1054 | -0.1452 | -0.0405 |
| 64 | -0.0859 | -0.3712 | 0.0834 | -0.2281 | 0.4280 | -0.0623 | -0.1387 |
| 65 | -0.0568 | -0.2885 | -0.3492 | -0.1127 | 0.0111 | -0.2650 | -0.1025 |
| 66 | -0.0568 | -0.2885 | -0.3492 | -0.1127 | 0.0111 | -0.2650 | -0.1025 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 56 | . | . | . | . | . | . |
| 57 | . | . | . | . | . | . |
| 58 | . | . | . | . | . | . |
| 59 | . | . | . | . | . | . |
| 60 | . | . | . | . | . | . |
| 61 | -0.0886 | 0.046 | 0.30 | 0.079 | -0.2100 | 0.2629 |
| 62 | -0.1843 | -0.122 | -0.08 | 0.269 | -0.0029 | -0.0329 |
| 63 | -0.1330 | 0.213 | 0.05 | 0.403 | 0.0268 | -0.2335 |
| 64 | 0.1752 | 0.046 | 0.05 | -0.254 | -0.1502 | 0.0054 |
| 65 | 0.0909 | -0.104 | -0.03 | 0.547 | 0.0029 | 0.1233 |
| 66 | 0.0909 | -0.104 | -0.03 | 0.547 | 0.0029 | 0.1233 |



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APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 67 | 4 | MEAN | | 14.2708 | 11.2396 | 27.9625 | 28.3187 |
| 68 | 4 | STD | | 12.0774 | 11.8346 | 4.0277 | 4.2079 |
| 69 | 4 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 70 | 4 | CORR | LYNGBYA | 0.0950 | -0.0410 | 0.0678 | 0.1243 |
| 71 | 4 | CORR | SARGASSU | . | . | . | . |
| 72 | 4 | CORR | ACETABUL | . | . | . | . |
| 73 | 4 | CORR | BATOPHOR | -0.2332 | -0.1820 | 0.2039 | 0.1257 |
| 74 | 4 | CORR | CHARA | -0.3423 | -0.2731 | -0.0191 | -0.1102 |
| 75 | 4 | CORR | CLADOPHO | . | . | . | . |
| 76 | 4 | CORR | HALIMEDA | . | . | . | . |
| 77 | 4 | CORR | PENICILL | . | . | . | . |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 67 | 2.5238 | 80.1458 | 2.7879 | 1.1457 | 1312.94 | 7.3167 | 6.0823 |
| 68 | 3.4296 | 12.6418 | 1.3443 | 0.3505 | 503.31 | 8.7006 | 8.7078 |
| 69 | 21.0000 | 24.0000 | 19.0000 | 20.0000 | 17.00 | 21.0000 | 11.0000 |
| 70 | -0.1177 | 0.1045 | 0.2146 | -0.0903 | -0.60 | -0.2001 | -0.1974 |
| 71 | . | . | . | . | . | . | . |
| 72 | . | . | . | . | . | . | . |
| 73 | -0.0337 | -0.0040 | -0.1908 | -0.1393 | 0.21 | 0.1578 | -0.1698 |
| 74 | -0.1191 | 0.0018 | 0.1254 | -0.1199 | 0.05 | -0.2040 | -0.2139 |
| 75 | . | . | . | . | . | . | . |
| 76 | . | . | . | . | . | . | . |
| 77 | . | . | . | . | . | . | . |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 67 | 3.3333 | 3.8909 | 81.1783 | 4.9278 | 0.1697 | 1.1152 | 2.5208 |
| 68 | 4.0014 | 12.4942 | 21.7066 | 1.8384 | 0.1456 | 0.8722 | 2.7318 |
| 69 | 21.0000 | 11.0000 | 21.0000 | 21.0000 | 21.0000 | 18.0000 | 24.0000 |
| 70 | -0.1569 | -0.0980 | -0.4926 | -0.3935 | -0.1182 | -0.0777 | 0.1398 |
| 71 | . | . | . | . | . | . | . |
| 72 | . | . | . | . | . | . | . |
| 73 | 0.0891 | -0.1517 | -0.3824 | -0.1913 | -0.2084 | -0.1855 | -0.1270 |
| 74 | -0.2130 | -0.0946 | 0.2050 | 0.5213 | -0.1638 | -0.0059 | -0.0556 |
| 75 | . | . | . | . | . | . | . |
| 76 | . | . | . | . | . | . | . |
| 77 | . | . | . | . | . | . | . |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 67 | 19.5938 | 125.438 | 1501.46 | 287.413 | 30.3689 | 8.0150 |
| 68 | 16.5721 | 99.873 | 674.94 | 233.460 | 56.3616 | 0.3496 |
| 69 | 24.0000 | 24.000 | 24.00 | 24.000 | 24.0000 | 18.0000 |
| 70 | -0.1232 | -0.151 | -0.21 | -0.082 | 0.0155 | 0.1580 |
| 71 | . | . | . | . | . | . |
| 72 | . | . | . | . | . | . |
| 73 | -0.1937 | -0.227 | 0.12 | 0.503 | -0.0444 | -0.2372 |
| 74 | -0.1899 | -0.270 | 0.03 | 0.401 | -0.0514 | -0.5044 |
| 75 | . | . | . | . | . | . |
| 76 | . | . | . | . | . | . |
| 77 | . | . | . | . | . | . |



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APPENDIX C. -- Continued (Plant Variables).

*** PLANT VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 78 | 4 | CORR | RHIZOCLO | . | . | . | . |
| 79 | 4 | CORR | UDOTEA | . | . | . | . |
| 80 | 4 | CORR | LAURENCI | . | . | . | . |
| 81 | 4 | CORR | LAUR_POL | . | . | . | . |
| 82 | 4 | CORR | POLYSIPH | . | . | . | . |
| 83 | 4 | CORR | HALODULE | -0.1875 | -0.1364 | 0.1784 | 0.2238 |
| 84 | 4 | CORR | RUPPIA | -0.0269 | 0.0465 | -0.1952 | -0.2135 |
| 85 | 4 | CORR | RUP_HALO | . | . | . | . |
| 86 | 4 | CORR | THALASSI | . | . | . | . |
| 87 | 4 | CORR | PLNT_TOT | 0.0523 | -0.0689 | 0.0777 | 0.1337 |
| 88 | 4 | CORR | NOLYNG | -0.3066 | -0.1945 | 0.0660 | 0.0589 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 78 | . | . | . | . | . | . | . |
| 79 | . | . | . | . | . | . | . |
| 80 | . | . | . | . | . | . | . |
| 81 | . | . | . | . | . | . | . |
| 82 | . | . | . | . | . | . | . |
| 83 | 0.2194 | -0.3386 | 0.1120 | 0.0204 | -0.47 | 0.0436 | -0.0604 |
| 84 | -0.0280 | 0.2773 | -0.0001 | 0.3326 | 0.01 | -0.1666 | -0.1809 |
| 85 | . | . | . | . | . | . | . |
| 86 | . | . | . | . | . | . | . |
| 87 | -0.1017 | 0.0856 | 0.2300 | -0.0648 | -0.63 | -0.2142 | -0.2191 |
| 88 | 0.1457 | -0.1391 | 0.1070 | 0.2251 | -0.40 | -0.1007 | -0.1948 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 78 | . | . | . | . | . | . | . |
| 79 | . | . | . | . | . | . | . |
| 80 | . | . | . | . | . | . | . |
| 81 | . | . | . | . | . | . | . |
| 82 | . | . | . | . | . | . | . |
| 83 | -0.0410 | -0.1412 | 0.3127 | 0.3218 | -0.2010 | 0.3117 | -0.0572 |
| 84 | -0.0989 | -0.1258 | -0.0201 | -0.0888 | 0.3198 | -0.0369 | 0.0890 |
| 85 | . | . | . | . | . | . | . |
| 86 | . | . | . | . | . | . | . |
| 87 | -0.1735 | -0.1197 | -0.4665 | -0.3660 | -0.1163 | -0.0524 | 0.1364 |
| 88 | -0.1257 | -0.2108 | 0.2671 | 0.2696 | 0.0276 | 0.2317 | -0.0322 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 78 | . | . | . | . | . | . |
| 79 | . | . | . | . | . | . |
| 80 | . | . | . | . | . | . |
| 81 | . | . | . | . | . | . |
| 82 | . | . | . | . | . | . |
| 83 | -0.0782 | -0.038 | -0.15 | 0.290 | -0.0150 | 0.2890 |
| 84 | -0.0505 | -0.118 | -0.23 | -0.193 | -0.0628 | -0.2848 |
| 85 | . | . | . | . | . | . |
| 86 | . | . | . | . | . | . |
| 87 | -0.1491 | -0.182 | -0.25 | -0.036 | 0.0058 | 0.1465 |
| 88 | -0.1758 | -0.206 | -0.24 | 0.323 | -0.0689 | -0.1059 |

APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 1 | 1 | MEAN | | 30.0625 | 29.7542 | 27.9375 | 27.8896 |
| 2 | 1 | STD | | 8.7444 | 8.7702 | 4.3295 | 4.3070 |
| 3 | 1 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 4 | 1 | CORR | EPINET_F | 0.5260 | 0.5459 | 0.4526 | 0.4326 |
| 5 | 1 | CORR | SHCORE_F | -0.6318 | -0.6212 | 0.1694 | 0.1431 |
| 6 | 1 | CORR | DPCORE_F | 0.2600 | 0.2919 | 0.2001 | 0.2116 |
| 7 | 1 | CORR | DOME_FAU | 0.3036 | 0.3173 | 0.2946 | 0.2856 |
| 8 | 1 | CORR | ANNELIDS | 0.5274 | 0.5547 | 0.2832 | 0.2846 |
| 9 | 1 | CORR | ARTHROPO | 0.2241 | 0.2087 | 0.3573 | 0.3050 |
| 10 | 1 | CORR | CHAETOGN | -0.1747 | -0.1628 | 0.0156 | 0.0189 |
| 11 | 1 | CORR | CNIDARIA | -0.1489 | -0.1364 | 0.0949 | 0.1012 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 1 | 4.3810 | 85.2083 | 2.5969 | 1.0980 | 1509.00 | 12.7789 | 3.2900 |
| 2 | 5.2581 | 18.2316 | 0.9716 | 1.1920 | 542.50 | 10.6297 | 2.9104 |
| 3 | 21.0000 | 24.0000 | 21.0000 | 19.0000 | 20.00 | 19.0000 | 5.0000 |
| 4 | 0.6609 | 0.3338 | 0.2107 | 0.1679 | 0.40 | -0.0126 | 0.6229 |
| 5 | 0.0084 | 0.0136 | 0.7213 | 0.0103 | -0.31 | 0.2276 | 0.6003 |
| 6 | 0.1887 | -0.1698 | -0.0271 | -0.1690 | -0.13 | 0.2882 | -0.2094 |
| 7 | -0.2514 | 0.0708 | 0.1445 | -0.3060 | 0.14 | 0.6594 | 0.0279 |
| 8 | 0.8284 | 0.3637 | 0.0014 | 0.2553 | 0.25 | -0.1664 | 0.7623 |
| 9 | -0.0856 | -0.1057 | 0.4683 | -0.2191 | 0.34 | 0.3546 | 0.0972 |
| 10 | -0.2085 | 0.1716 | 0.0674 | -0.1087 | 0.09 | -0.1453 | -0.6523 |
| 11 | -0.2553 | 0.1461 | 0.1078 | -0.1313 | 0.16 | -0.1635 | 0.9157 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 1 | 4.9158 | 1.5200 | 111.948 | 5.4274 | 0.3018 | 0.9916 | 2.3196 |
| 2 | 5.0541 | 2.2070 | 18.297 | 1.5853 | 0.2251 | 0.7954 | 2.3263 |
| 3 | 19.0000 | 5.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 4 | -0.2000 | 0.8208 | 0.167 | -0.3135 | 0.1351 | 0.0808 | -0.1513 |
| 5 | -0.0033 | 0.1005 | -0.159 | 0.1114 | -0.1314 | 0.0431 | 0.4891 |
| 6 | 0.1024 | -0.1570 | 0.024 | -0.2461 | -0.0009 | -0.3493 | -0.4091 |
| 7 | 0.3848 | 0.5238 | 0.114 | -0.2934 | 0.1681 | -0.0814 | -0.2317 |
| 8 | -0.2060 | 0.9001 | 0.132 | -0.1644 | -0.0004 | 0.0084 | -0.1217 |
| 9 | 0.0296 | 0.7362 | 0.156 | -0.3614 | 0.3565 | 0.0605 | -0.0880 |
| 10 | 0.0387 | -0.8889 | -0.033 | -0.0257 | 0.0541 | -0.0708 | -0.2042 |
| 11 | -0.0463 | 0.2471 | 0.018 | -0.0332 | 0.0139 | -0.0417 | -0.2510 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 1 | 13.6583 | 89.413 | 1253.91 | 332.355 | 20.6451 | 8.1142 |
| 2 | 10.9874 | 55.759 | 221.21 | 289.304 | 22.6417 | 0.3993 |
| 3 | 24.0000 | 23.000 | 23.00 | 23.000 | 23.0000 | 19.0000 |
| 4 | 0.3137 | -0.259 | 0.18 | 0.048 | -0.2242 | -0.1008 |
| 5 | -0.0385 | -0.112 | 0.08 | -0.008 | 0.2328 | 0.2365 |
| 6 | -0.1761 | 0.457 | -0.11 | -0.070 | -0.4144 | 0.5026 |
| 7 | -0.1300 | 0.080 | 0.30 | 0.181 | -0.2065 | 0.5187 |
| 8 | 0.3640 | -0.202 | 0.01 | -0.162 | -0.2135 | 0.3568 |
| 9 | 0.0622 | -0.037 | 0.29 | 0.073 | 0.0153 | -0.4017 |
| 10 | -0.2810 | -0.082 | 0.10 | 0.952 | -0.2120 | -0.0495 |
| 11 | -0.3313 | 0.260 | 0.07 | 0.962 | -0.2159 | 0.0072 |



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APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 12 | 1 | CORR | ECHINODE | 0.1129 | 0.1185 | 0.2891 | 0.2804 |
| 13 | 1 | CORR | MOLLUSKS | -0.1913 | -0.1874 | 0.2882 | 0.2672 |
| 14 | 1 | CORR | NEMERTEA | -0.1349 | -0.0658 | 0.2239 | 0.2052 |
| 15 | 1 | CORR | SIPUNCUL | 0.0135 | 0.0043 | 0.2553 | 0.2408 |
| 16 | 1 | CORR | VERTEBRA | 0.0801 | 0.0834 | 0.1676 | 0.1619 |
| 17 | 1 | CORR | TOT_ESFA | 0.4926 | 0.5132 | 0.4422 | 0.4214 |
| 18 | 1 | CORR | FAUN_TOT | 0.5054 | 0.5258 | 0.4547 | 0.4331 |
| 19 | 2 | MEAN | | 25.9417 | 24.0375 | 28.0250 | 28.1292 |
| 20 | 2 | STD | | 10.0245 | 11.0020 | 4.1894 | 4.0934 |
| 21 | 2 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 22 | 2 | CORR | EPINET_F | 0.5039 | 0.5355 | 0.3773 | 0.3793 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 12 | -0.1186 | -0.1233 | 0.2626 | -0.1864 | 0.30 | 0.4431 | -0.1650 |
| 13 | -0.1117 | 0.2075 | 0.3542 | -0.0849 | 0.22 | 0.1533 | 0.9211 |
| 14 | 0.1039 | 0.1023 | 0.0652 | 0.0115 | -0.46 | 0.1900 | 0.0443 |
| 15 | -0.1154 | -0.1120 | 0.2169 | -0.3185 | 0.06 | 0.1983 | -0.1650 |
| 16 | -0.1507 | -0.4432 | 0.4341 | -0.0128 | 0.25 | -0.0178 | . |
| 17 | 0.6542 | 0.3309 | 0.2485 | 0.1157 | 0.39 | 0.0036 | 0.6432 |
| 18 | 0.6605 | 0.3277 | 0.2420 | 0.1612 | 0.39 | 0.0107 | 0.6614 |
| 19 | 3.1000 | 78.2500 | 2.6011 | 1.2346 | 1538.00 | 15.3275 | 3.7250 |
| 20 | 4.5757 | 13.1033 | 1.0862 | 0.7652 | 594.97 | 15.5188 | 5.2219 |
| 21 | 20.0000 | 24.0000 | 21.0000 | 20.0000 | 20.00 | 20.0000 | 6.0000 |
| 22 | 0.2889 | 0.1563 | 0.2976 | -0.0191 | 0.36 | 0.2164 | 0.7122 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 12 | 0.1655 | -0.0705 | 0.061 | -0.1899 | 0.0281 | 0.0778 | 0.1114 |
| 13 | -0.1264 | 0.5381 | -0.131 | -0.1794 | 0.0701 | 0.3059 | 0.0542 |
| 14 | 0.1734 | -0.0705 | -0.195 | -0.2781 | 0.1876 | -0.1944 | -0.1480 |
| 15 | 0.0624 | -0.0083 | -0.299 | -0.2765 | -0.0303 | -0.2041 | -0.3419 |
| 16 | -0.2040 | . | 0.162 | 0.1566 | -0.4113 | -0.1763 | -0.0500 |
| 17 | -0.1927 | 0.8369 | 0.142 | -0.3120 | 0.1358 | 0.0703 | -0.1424 |
| 18 | -0.1952 | 0.8350 | 0.159 | -0.3154 | 0.1367 | 0.0732 | -0.1427 |
| 19 | 4.8025 | 2.6167 | 104.249 | 5.5758 | 0.2159 | 0.9455 | 2.3043 |
| 20 | 3.4793 | 4.4388 | 12.174 | 1.3219 | 0.1342 | 0.4783 | 2.7620 |
| 21 | 20.0000 | 6.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 22 | 0.0960 | 0.5893 | 0.523 | -0.4720 | 0.7865 | 0.1685 | -0.2272 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 12 | -0.1359 | -0.116 | 0.33 | -0.060 | 0.1559 | -0.0679 |
| 13 | -0.0911 | -0.398 | 0.29 | 0.575 | 0.0233 | -0.0837 |
| 14 | -0.2466 | 0.004 | 0.11 | 0.240 | -0.1616 | -0.5510 |
| 15 | -0.3638 | 0.481 | 0.19 | 0.575 | -0.3430 | 0.2078 |
| 16 | -0.3026 | -0.088 | -0.04 | 0.218 | 0.1165 | -0.0672 |
| 17 | 0.2875 | -0.252 | 0.17 | 0.064 | -0.2150 | -0.0130 |
| 18 | 0.2949 | -0.252 | 0.18 | 0.056 | -0.2167 | -0.0555 |
| 19 | 15.1917 | 106.045 | 1238.96 | 269.057 | 21.9233 | 8.3021 |
| 20 | 10.9274 | 71.446 | 275.29 | 148.583 | 27.8158 | 0.4324 |
| 21 | 24.0000 | 22.000 | 24.00 | 24.000 | 23.0000 | 17.0000 |
| 22 | 0.1739 | -0.106 | 0.52 | -0.165 | -0.2672 | 0.6947 |

APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 23 | 2 | CORR | SHCORE_F | 0.3990 | 0.3749 | 0.3003 | 0.2857 |
| 24 | 2 | CORR | DPCORE_F | 0.4400 | 0.4446 | 0.1609 | 0.1590 |
| 25 | 2 | CORR | DOME_FAU | 0.4930 | 0.4965 | 0.2182 | 0.2180 |
| 26 | 2 | CORR | ANNELIDS | 0.3922 | 0.4074 | 0.2675 | 0.2656 |
| 27 | 2 | CORR | ARTHROPO | 0.6477 | 0.6554 | 0.6127 | 0.6123 |
| 28 | 2 | CORR | CHAETOGN | -0.1549 | -0.1158 | -0.0724 | -0.0830 |
| 29 | 2 | CORR | CNIDARIA | 0.3061 | 0.3095 | 0.4698 | 0.4649 |
| 30 | 2 | CORR | ECHINODE | 0.5034 | 0.5127 | 0.2487 | 0.2489 |
| 31 | 2 | CORR | MOLLUSKS | 0.1065 | 0.1432 | 0.0933 | 0.0936 |
| 32 | 2 | CORR | NEMERTEA | 0.1153 | 0.1192 | 0.2157 | 0.2061 |
| 33 | 2 | CORR | SIPUNCUL | 0.4309 | 0.4566 | 0.2473 | 0.2447 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 23 | -0.1005 | -0.3024 | -0.1323 | -0.0452 | 0.19 | 0.3302 | 0.7842 |
| 24 | 0.2195 | -0.1622 | 0.1264 | -0.0833 | 0.19 | 0.2361 | 0.8662 |
| 25 | 0.1908 | -0.0673 | -0.0825 | -0.0354 | 0.09 | 0.1448 | 0.8568 |
| 26 | 0.4339 | 0.0404 | 0.4341 | 0.1372 | 0.26 | 0.4671 | -0.3116 |
| 27 | -0.2209 | 0.1446 | -0.2818 | -0.1608 | 0.46 | -0.0977 | 0.5170 |
| 28 | -0.0656 | 0.3763 | 0.1266 | 0.0712 | 0.10 | -0.1494 | -0.2614 |
| 29 | -0.3420 | 0.1759 | -0.0825 | -0.2355 | 0.33 | -0.1870 | 0.8991 |
| 30 | -0.1412 | 0.1263 | -0.3859 | -0.0028 | 0.17 | -0.1699 | . |
| 31 | -0.0382 | 0.0054 | 0.0759 | -0.2255 | 0.26 | -0.1968 | 0.8642 |
| 32 | -0.3083 | 0.3226 | -0.0914 | -0.1441 | 0.27 | -0.2844 | 0.8486 |
| 33 | 0.2282 | -0.0001 | 0.2691 | -0.0583 | 0.41 | 0.1800 | 0.9148 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 23 | 0.2708 | 0.6615 | 0.3313 | -0.3908 | 0.4254 | -0.0996 | -0.3732 |
| 24 | 0.2052 | 0.7556 | 0.4452 | -0.3643 | 0.6240 | -0.2123 | -0.3402 |
| 25 | -0.0094 | 0.7512 | 0.4373 | -0.3808 | 0.5637 | -0.1417 | -0.2724 |
| 26 | 0.3694 | -0.4242 | 0.3435 | -0.3878 | 0.6010 | 0.3740 | -0.2044 |
| 27 | -0.3317 | 0.3566 | 0.3977 | -0.5981 | 0.6424 | 0.2421 | -0.2562 |
| 28 | -0.1277 | -0.3051 | 0.2516 | 0.1128 | 0.1854 | 0.4337 | -0.1693 |
| 29 | -0.2957 | 0.7942 | 0.2535 | -0.3652 | 0.3158 | 0.1732 | 0.4827 |
| 30 | -0.3521 | . | 0.3014 | -0.2178 | 0.2142 | 0.0848 | -0.0986 |
| 31 | -0.1335 | 0.7526 | 0.3467 | -0.1420 | 0.4199 | -0.0332 | -0.1754 |
| 32 | -0.3480 | 0.8346 | 0.5583 | -0.0957 | 0.3940 | 0.3972 | 0.2868 |
| 33 | 0.1539 | 0.8079 | 0.5393 | -0.3556 | 0.6830 | -0.0266 | -0.2449 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 23 | -0.1648 | 0.673 | 0.12 | 0.020 | -0.3577 | 0.4933 |
| 24 | -0.0461 | 0.036 | 0.17 | 0.009 | -0.2862 | 0.6648 |
| 25 | -0.0198 | -0.036 | 0.19 | -0.039 | -0.2324 | 0.7330 |
| 26 | 0.1596 | 0.084 | 0.52 | -0.191 | -0.2241 | 0.5132 |
| 27 | 0.2030 | 0.200 | 0.41 | -0.222 | -0.3749 | 0.5754 |
| 28 | -0.1872 | -0.154 | 0.09 | 0.198 | -0.1792 | -0.4447 |
| 29 | 0.0596 | 0.361 | 0.42 | -0.098 | 0.1085 | 0.5502 |
| 30 | 0.2593 | -0.129 | 0.12 | -0.268 | -0.1361 | 0.2095 |
| 31 | -0.1766 | -0.301 | 0.04 | 0.191 | -0.1343 | 0.4398 |
| 32 | 0.1122 | 0.094 | 0.30 | -0.082 | -0.0875 | 0.3406 |
| 33 | 0.0502 | -0.158 | 0.38 | -0.050 | -0.2229 | 0.6554 |

APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 34 | 2 | CORR | VERTEBRA | -0.0474 | -0.0313 | 0.2650 | 0.3107 |
| 35 | 2 | CORR | TOT_ESFA | 0.4974 | 0.5216 | 0.3766 | 0.3750 |
| 36 | 2 | CORR | FAUN_TOT | 0.5308 | 0.5553 | 0.4272 | 0.4278 |
| 37 | 3 | MEAN | | 18.4667 | 16.5792 | 27.8438 | 28.4275 |
| 38 | 3 | STD | | 12.0470 | 12.2420 | 3.9662 | 4.3545 |
| 39 | 3 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 40 | 3 | CORR | EPINET_F | -0.0247 | -0.0200 | -0.0183 | 0.0284 |
| 41 | 3 | CORR | SHCORE_F | 0.0920 | 0.0602 | 0.1460 | 0.2118 |
| 42 | 3 | CORR | DPCORE_F | -0.1883 | -0.2027 | 0.2820 | 0.3015 |
| 43 | 3 | CORR | DOME_FAU | 0.1335 | 0.1691 | 0.1207 | 0.1045 |
| 44 | 3 | CORR | ANNELIDS | 0.0129 | -0.0047 | 0.1203 | 0.1619 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 34 | 0.0365 | 0.2762 | -0.1545 | -0.2770 | -0.40 | -0.2321 | -0.0833 |
| 35 | 0.3428 | 0.0678 | 0.3607 | 0.0402 | 0.38 | 0.3556 | 0.6874 |
| 36 | 0.2515 | 0.0942 | 0.2528 | -0.0309 | 0.40 | 0.2514 | 0.7323 |
| 37 | 3.0000 | 78.6875 | 2.7565 | 1.2316 | 1183.89 | 11.8976 | 7.6050 |
| 38 | 3.1623 | 17.1634 | 1.2521 | 0.6212 | 481.64 | 9.8408 | 7.7415 |
| 39 | 19.0000 | 24.0000 | 21.0000 | 21.0000 | 18.00 | 21.0000 | 10.0000 |
| 40 | -0.1023 | 0.2324 | -0.0411 | -0.2232 | -0.61 | -0.3424 | -0.3612 |
| 41 | -0.3959 | -0.2830 | 0.0557 | -0.1315 | -0.13 | 0.2770 | 0.4940 |
| 42 | -0.3482 | -0.3421 | -0.0972 | -0.1857 | 0.05 | -0.0264 | -0.1467 |
| 43 | -0.2866 | -0.2162 | -0.1304 | 0.3023 | 0.19 | 0.5588 | -0.0978 |
| 44 | -0.2984 | -0.5139 | 0.1157 | -0.1030 | -0.21 | 0.2535 | 0.4667 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 34 | -0.3191 | 0.0087 | -0.0710 | -0.2045 | 0.1609 | 0.1704 | -0.0699 |
| 35 | 0.2388 | 0.5405 | 0.4696 | -0.4930 | 0.7623 | 0.1827 | -0.2683 |
| 36 | 0.1217 | 0.6094 | 0.5252 | -0.5286 | 0.8103 | 0.1755 | -0.2837 |
| 37 | 4.8833 | 2.9950 | 92.8923 | 5.4464 | 0.1845 | 0.9692 | 2.4043 |
| 38 | 5.4227 | 3.2609 | 10.6234 | 1.5135 | 0.1060 | 0.5843 | 2.9925 |
| 39 | 21.0000 | 10.0000 | 21.0000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 40 | -0.3727 | -0.4844 | -0.6676 | -0.2685 | -0.0244 | -0.2852 | 0.2268 |
| 41 | 0.3458 | -0.1172 | 0.1363 | -0.0305 | -0.0141 | -0.0214 | -0.4120 |
| 42 | -0.1077 | -0.3750 | -0.0928 | -0.1234 | 0.0442 | -0.1079 | -0.2850 |
| 43 | 0.5694 | -0.1772 | -0.0034 | -0.1253 | 0.0186 | 0.0302 | -0.2366 |
| 44 | 0.4464 | -0.1465 | 0.1508 | 0.0155 | -0.0165 | 0.1364 | -0.3251 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 34 | 0.4865 | -0.178 | 0.07 | -0.212 | -0.1283 | 0.5374 |
| 35 | 0.1416 | 0.038 | 0.55 | -0.169 | -0.3008 | 0.6392 |
| 36 | 0.1536 | 0.022 | 0.54 | -0.173 | -0.3401 | 0.7014 |
| 37 | 17.9981 | 103.688 | 1355.63 | 262.507 | 26.9364 | 8.0333 |
| 38 | 20.0639 | 70.890 | 323.58 | 142.904 | 36.9810 | 0.3094 |
| 39 | 24.0000 | 24.000 | 24.00 | 24.000 | 23.0000 | 18.0000 |
| 40 | 0.0179 | -0.327 | -0.31 | 0.167 | 0.2083 | 0.2067 |
| 41 | 0.3166 | 0.489 | 0.08 | -0.084 | -0.4152 | 0.1648 |
| 42 | 0.4039 | 0.395 | 0.31 | -0.343 | -0.2963 | 0.1534 |
| 43 | -0.1489 | 0.721 | 0.08 | 0.281 | -0.2070 | 0.4232 |
| 44 | 0.2376 | 0.459 | 0.03 | 0.101 | -0.2517 | 0.0794 |



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APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 45 | 3 | CORR | ARTHROPO | 0.0112 | 0.0018 | 0.0346 | 0.0834 |
| 46 | 3 | CORR | CHAETOGN | . | . | . | . |
| 47 | 3 | CORR | CNIDARIA | . | . | . | . |
| 48 | 3 | CORR | ECHINODE | . | . | . | . |
| 49 | 3 | CORR | MOLLUSKS | -0.1038 | -0.1147 | 0.1268 | 0.1930 |
| 50 | 3 | CORR | NEMERTEA | 0.5251 | 0.5296 | 0.3692 | 0.3293 |
| 51 | 3 | CORR | SIPUNCUL | 0.0188 | 0.0682 | -0.1890 | -0.2015 |
| 52 | 3 | CORR | VERTEBRA | 0.3251 | 0.3061 | 0.2510 | 0.2407 |
| 53 | 3 | CORR | TOT_ESFA | 0.0073 | -0.0094 | 0.1364 | 0.2125 |
| 54 | 3 | CORR | FAUN_TOT | -0.0068 | -0.0247 | 0.1399 | 0.2176 |
| 55 | 4 | MEAN | | 14.2708 | 11.2396 | 27.9625 | 28.3187 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 45 | -0.1550 | 0.1502 | -0.0429 | -0.2634 | -0.58 | -0.3170 | -0.2236 |
| 46 | . | . | . | . | . | . | . |
| 47 | . | . | . | . | . | . | . |
| 48 | . | . | . | . | . | . | . |
| 49 | -0.3016 | -0.0625 | 0.2743 | -0.0979 | -0.56 | 0.0329 | -0.0694 |
| 50 | 0.0905 | -0.6045 | 0.1757 | 0.0093 | 0.15 | 0.4200 | 0.8621 |
| 51 | 0.1196 | 0.0316 | -0.1728 | 0.0224 | -0.40 | 0.0610 | |
| 52 | 0.2048 | -0.1722 | 0.1318 | -0.1565 | 0.07 | 0.4030 | . |
| 53 | -0.3706 | -0.2374 | 0.1145 | -0.2750 | -0.49 | -0.0417 | -0.3021 |
| 54 | -0.4026 | -0.2326 | 0.1155 | -0.2669 | -0.50 | -0.0521 | -0.0363 |
| 55 | 2.5238 | 80.1458 | 2.7879 | 1.1457 | 1312.94 | 7.3167 | -0.0372 |
| | | | | | | | 6.0823 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 45 | -0.2718 | -0.4658 | -0.6409 | -0.3340 | 0.1047 | -0.2148 | 0.1656 |
| 46 | . | . | . | . | . | . | . |
| 47 | . | . | . | . | . | . | . |
| 48 | . | . | . | . | . | . | . |
| 49 | -0.1777 | -0.2188 | -0.0718 | 0.0181 | -0.2302 | -0.4562 | -0.4040 |
| 50 | 0.2302 | 0.0975 | 0.2513 | -0.1048 | -0.1645 | 0.1158 | -0.2236 |
| 51 | -0.1132 | . | -0.2037 | 0.1321 | -0.5334 | -0.4505 | -0.2209 |
| 52 | 0.1565 | -0.3389 | 0.2130 | -0.0558 | -0.0458 | -0.0033 | 0.0060 |
| 53 | 0.0209 | -0.4899 | -0.3901 | -0.2177 | -0.0459 | -0.2273 | -0.2168 |
| 54 | -0.0045 | -0.4939 | -0.3900 | -0.2187 | -0.0422 | -0.2435 | -0.2173 |
| 55 | 3.3333 | 3.8909 | 81.1783 | 4.9278 | 0.1697 | 1.1152 | 2.5208 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 45 | -0.0318 | -0.225 | -0.24 | 0.219 | 0.1246 | 0.1300 |
| 46 | . | . | . | . | . | . |
| 47 | . | . | . | . | . | . |
| 48 | . | . | . | . | . | . |
| 49 | 0.4631 | 0.119 | -0.18 | -0.327 | -0.3222 | 0.3374 |
| 50 | 0.1340 | -0.021 | 0.44 | -0.262 | -0.2537 | 0.0355 |
| 51 | -0.1367 | 0.015 | -0.29 | 0.074 | -0.1592 | 0.4628 |
| 52 | 0.0353 | -0.277 | 0.21 | -0.217 | -0.0956 | 0.3753 |
| 53 | 0.2500 | 0.145 | -0.21 | 0.115 | -0.1759 | 0.2948 |
| 54 | 0.2633 | 0.172 | -0.19 | 0.106 | -0.1778 | 0.2974 |
| 55 | 19.5938 | 125.438 | 1501.46 | 287.413 | 30.3689 | 8.0150 |

APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 56 | 4 | STD | | 12.0774 | 11.8346 | 4.0277 | 4.2079 |
| 57 | 4 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 58 | 4 | CORR | EPINET_F | -0.2615 | -0.2205 | -0.1378 | -0.0746 |
| 59 | 4 | CORR | SHCORE_F | -0.1682 | -0.0725 | -0.2063 | -0.2344 |
| 60 | 4 | CORR | DPCORE_F | 0.3856 | 0.4423 | 0.2755 | 0.2308 |
| 61 | 4 | CORR | DOME_FAU | 0.0944 | 0.1559 | 0.0538 | 0.0247 |
| 62 | 4 | CORR | ANNELIDS | 0.1092 | 0.1317 | -0.0718 | -0.0743 |
| 63 | 4 | CORR | ARTHROPO | -0.4933 | -0.4199 | -0.4523 | -0.4233 |
| 64 | 4 | CORR | CHAETOGN | 0.0178 | 0.0874 | -0.1029 | -0.1138 |
| 65 | 4 | CORR | CNIDARIA | -0.0509 | -0.1028 | 0.1749 | 0.2449 |
| 66 | 4 | CORR | ECHINODE | . | . | . | . |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 56 | 3.4296 | 12.6418 | 1.3443 | 0.3505 | 503.31 | 8.7006 | 8.7078 |
| 57 | 21.0000 | 24.0000 | 19.0000 | 20.0000 | 17.00 | 21.0000 | 11.0000 |
| 58 | 0.2493 | -0.1383 | 0.1604 | 0.1206 | -0.71 | -0.0440 | -0.0452 |
| 59 | -0.0461 | -0.3300 | 0.4984 | 0.0573 | -0.14 | 0.1035 | 0.5832 |
| 60 | -0.1850 | -0.2301 | -0.1541 | 0.0979 | 0.01 | 0.7389 | -0.0724 |
| 61 | -0.1686 | -0.3796 | 0.0816 | -0.2025 | 0.22 | 0.1734 | . |
| 62 | 0.1683 | -0.2805 | 0.5135 | 0.1230 | -0.21 | 0.1329 | 0.7435 |
| 63 | 0.3910 | -0.1534 | 0.3011 | -0.0999 | -0.19 | -0.1018 | 0.3066 |
| 64 | 0.0887 | -0.2640 | 0.7290 | 0.3984 | -0.83 | 0.2998 | . |
| 65 | -0.1196 | -0.2528 | -0.3398 | -0.1097 | -0.14 | -0.0762 | 0.1280 |
| 66 | . | . | . | . | . | . | . |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 56 | 4.0014 | 12.4942 | 21.7066 | 1.8384 | 0.1456 | 0.8722 | 2.7318 |
| 57 | 21.0000 | 11.0000 | 21.0000 | 21.0000 | 21.0000 | 18.0000 | 24.0000 |
| 58 | -0.3025 | -0.1533 | 0.3278 | 0.4694 | -0.2407 | 0.3579 | 0.1002 |
| 59 | 0.1420 | 0.7098 | 0.0580 | 0.2783 | -0.4353 | -0.1094 | -0.2310 |
| 60 | 0.5504 | -0.1992 | 0.1433 | -0.0300 | 0.0052 | 0.5584 | -0.2271 |
| 61 | 0.4104 | . | 0.1471 | 0.0838 | -0.0669 | 0.1019 | -0.2099 |
| 62 | 0.0853 | 0.8224 | 0.1246 | 0.2088 | -0.3440 | -0.0872 | -0.2413 |
| 63 | -0.1656 | 0.3956 | 0.1389 | 0.5077 | -0.4688 | -0.1070 | -0.0429 |
| 64 | -0.0824 | . | 0.2092 | 0.2965 | -0.2686 | -0.1808 | -0.2066 |
| 65 | -0.1118 | -0.0925 | -0.0126 | 0.0340 | -0.1641 | 0.9355 | -0.1333 |
| 66 | . | . | . | . | . | . | . |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 56 | 16.5721 | 99.873 | 674.94 | 233.460 | 56.3616 | 0.3496 |
| 57 | 24.0000 | 24.000 | 24.00 | 24.000 | 24.0000 | 18.0000 |
| 58 | 0.1280 | -0.254 | -0.23 | -0.190 | 0.0729 | 0.0058 |
| 59 | -0.2348 | 0.495 | 0.03 | 0.063 | -0.2385 | -0.1349 |
| 60 | 0.1385 | -0.006 | 0.22 | -0.112 | -0.1298 | 0.0074 |
| 61 | -0.1978 | 0.463 | 0.02 | 0.346 | -0.1176 | . |
| 62 | -0.2629 | 0.272 | -0.14 | 0.252 | -0.1790 | 0.0113 |
| 63 | -0.2266 | 0.179 | 0.03 | 0.078 | -0.0606 | -0.2805 |
| 64 | -0.1298 | -0.025 | -0.18 | -0.102 | -0.1476 | 0.0343 |
| 65 | 0.5468 | -0.084 | -0.08 | -0.302 | -0.1380 | 0.0343 |
| 66 | . | . | . | . | . | . |



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APPENDIX C. -- Continued (Fauna Variables).

*** FAUNA VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 67 | 4 | CORR | MOLLUSKS | -0.2461 | -0.1319 | -0.0079 | -0.0562 |
| 68 | 4 | CORR | NEMERTEA | -0.0450 | 0.0540 | 0.3181 | 0.2198 |
| 69 | 4 | CORR | SIPUNCUL | . | . | . | . |
| 70 | 4 | CORR | VERTEBRA | . | . | . | . |
| 71 | 4 | CORR | TOT_ESFA | -0.2462 | -0.1575 | -0.2214 | -0.2304 |
| 72 | 4 | CORR | FAUN_TOT | -0.1469 | -0.0393 | -0.1438 | -0.1707 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 67 | -0.3476 | -0.6251 | 0.6460 | 0.0781 | -0.40 | 0.1044 | -0.1003 |
| 68 | -0.2130 | 0.0630 | 0.0767 | 0.3787 | 0.22 | 0.0213 | . |
| 69 | . | . | . | . | . | . | . |
| 70 | . | . | . | . | . | . | . |
| 71 | 0.1092 | -0.4436 | 0.6020 | 0.0572 | -0.32 | 0.0668 | 0.7035 |
| 72 | 0.0201 | -0.5437 | 0.5806 | 0.0680 | -0.33 | 0.2656 | 0.6747 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 67 | 0.0222 | -0.2198 | 0.1619 | 0.2979 | -0.2953 | 0.2863 | -0.2163 |
| 68 | -0.0625 | . | -0.0992 | -0.2438 | 0.1833 | -0.0203 | -0.2417 |
| 69 | . | . | . | . | . | . | . |
| 70 | . | . | . | . | . | . | . |
| 71 | -0.0208 | 0.7602 | 0.1716 | 0.4201 | -0.4834 | 0.0303 | -0.2333 |
| 72 | 0.1752 | 0.6992 | 0.1938 | 0.3976 | -0.4816 | 0.0385 | -0.3178 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 67 | -0.0043 | 0.237 | -0.01 | 0.024 | -0.2494 | -0.2344 |
| 68 | 0.1969 | 0.244 | 0.81 | 0.033 | -0.1927 | 0.0436 |
| 69 | . | . | . | . | . | . |
| 70 | . | . | . | . | . | . |
| 71 | -0.2199 | 0.306 | -0.05 | 0.170 | -0.2191 | -0.1938 |
| 72 | -0.1986 | 0.375 | 0.01 | 0.171 | -0.2832 | -0.2028 |

APPENDIX C. METABOLISM VARIABLES BEGIN ON NEXT PAGE.

*** METABOLISM VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 1 | 1 | MEAN | | 30.0625 | 29.7542 | 27.9375 | 27.8896 |
| 2 | 1 | STD | | 8.7444 | 8.7702 | 4.3295 | 4.3070 |
| 3 | 1 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 4 | 1 | CORR | OWMETSRF | 0.1449 | 0.1678 | 0.1446 | 0.1100 |
| 5 | 1 | CORR | OWMETBOT | 0.1345 | 0.1528 | 0.2847 | 0.2690 |
| 6 | 1 | CORR | OWMETAVG | 0.1488 | 0.1709 | 0.2242 | 0.1969 |
| 7 | 1 | CORR | LDMET_L | 0.2002 | 0.2097 | 0.2943 | 0.3006 |
| 8 | 1 | CORR | LDMET_M2 | 0.1480 | 0.1551 | 0.1661 | 0.1907 |
| 9 | 1 | CORR | DOME_MET | 0.1681 | 0.1705 | 0.3345 | 0.3147 |
| 10 | 2 | MEAN | | 25.9417 | 24.0375 | 28.0250 | 28.1292 |
| 11 | 2 | STD | | 10.0245 | 11.0020 | 4.1894 | 4.0934 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 1 | 4.3810 | 85.2083 | 2.5969 | 1.0980 | 1509.00 | 12.7789 | 3.2900 |
| 2 | 5.2581 | 18.2316 | 0.9716 | 1.1920 | 542.50 | 10.6297 | 2.9104 |
| 3 | 21.0000 | 24.0000 | 21.0000 | 19.0000 | 20.00 | 19.0000 | 5.0000 |
| 4 | -0.0634 | 0.0567 | 0.3529 | -0.1520 | 0.05 | 0.0714 | 0.1961 |
| 5 | -0.0435 | 0.2914 | 0.0609 | -0.1580 | 0.13 | 0.1356 | 0.5978 |
| 6 | -0.0547 | 0.1783 | 0.2285 | -0.1656 | 0.09 | 0.1234 | 0.4545 |
| 7 | -0.0893 | 0.5131 | -0.1056 | -0.2269 | 0.35 | 0.4488 | 0.8142 |
| 8 | -0.0169 | 0.5788 | -0.2340 | -0.0821 | 0.15 | 0.2653 | 0.8425 |
| 9 | 0.0501 | 0.1313 | -0.0230 | -0.0651 | 0.18 | -0.4444 | 0.8166 |
| 10 | 3.1000 | 78.2500 | 2.6011 | 1.2346 | 1538.00 | 15.3275 | 3.7250 |
| 11 | 4.5757 | 13.1033 | 1.0862 | 0.7652 | 594.97 | 15.5188 | 5.2219 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 1 | 4.9158 | 1.5200 | 111.948 | 5.4274 | 0.3018 | 0.9916 | 2.3196 |
| 2 | 5.0541 | 2.2070 | 18.297 | 1.5853 | 0.2251 | 0.7954 | 2.3263 |
| 3 | 19.0000 | 5.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 4 | 0.0300 | 0.0182 | 0.859 | 0.1101 | 0.6984 | 0.3202 | -0.0664 |
| 5 | 0.0909 | 0.5568 | 0.633 | -0.3556 | 0.9576 | 0.3457 | -0.0735 |
| 6 | 0.0728 | 0.2912 | 0.800 | -0.1171 | 0.8730 | 0.3537 | -0.0742 |
| 7 | 0.1763 | 0.3613 | 0.129 | -0.1816 | 0.1424 | 0.6762 | -0.0234 |
| 8 | 0.1228 | 0.3170 | 0.078 | -0.0704 | 0.0756 | 0.7111 | 0.0984 |
| 9 | -0.2981 | 0.3806 | 0.488 | -0.2061 | 0.5460 | 0.5888 | -0.0772 |
| 10 | 4.8025 | 2.6167 | 104.249 | 5.5758 | 0.2159 | 0.9455 | 2.3043 |
| 11 | 3.4793 | 4.4388 | 12.174 | 1.3219 | 0.1342 | 0.4783 | 2.7620 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 1 | 13.6583 | 89.413 | 1253.91 | 332.355 | 20.6451 | 8.1142 |
| 2 | 10.9874 | 55.759 | 221.21 | 289.304 | 22.6417 | 0.3993 |
| 3 | 24.0000 | 23.000 | 23.00 | 23.000 | 23.0000 | 19.0000 |
| 4 | -0.0598 | 0.152 | 0.26 | 0.201 | 0.2167 | 0.0737 |
| 5 | -0.0535 | 0.039 | 0.17 | 0.189 | 0.2708 | -0.0428 |
| 6 | -0.0604 | 0.105 | 0.23 | 0.208 | 0.2576 | 0.0211 |
| 7 | 0.0811 | -0.055 | 0.39 | -0.063 | -0.0911 | 0.4491 |
| 8 | 0.2545 | -0.231 | 0.27 | -0.268 | 0.0212 | 0.4095 |
| 9 | 0.1386 | 0.244 | 0.25 | -0.118 | 0.0809 | -0.2903 |
| 10 | 15.1917 | 106.045 | 1238.96 | 269.057 | 21.9233 | 8.3021 |
| 11 | 10.9274 | 71.446 | 275.29 | 148.583 | 27.8158 | 0.4324 |

APPENDIX C. -- Continued (Metabolism Variables).

*** METABOLISM VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 12 | 2 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 13 | 2 | CORR | OWMETSRF | 0.5310 | 0.5479 | 0.5860 | 0.5838 |
| 14 | 2 | CORR | OWMETBOT | 0.6049 | 0.6003 | 0.4442 | 0.4352 |
| 15 | 2 | CORR | OWMETAVG | 0.5862 | 0.5926 | 0.5317 | 0.5259 |
| 16 | 2 | CORR | LDMET_L | -0.0787 | -0.1073 | 0.3886 | 0.4024 |
| 17 | 2 | CORR | LDMET_M2 | -0.0965 | -0.1260 | 0.4005 | 0.4140 |
| 18 | 2 | CORR | DOME_MET | -0.2672 | -0.2677 | 0.1548 | 0.1623 |
| 19 | 3 | MEAN | | 18.4667 | 16.5792 | 27.8438 | 28.4275 |
| 20 | 3 | STD | | 12.0470 | 12.2420 | 3.9662 | 4.3545 |
| 21 | 3 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 22 | 3 | CORR | OWMETSRF | 0.0876 | 0.1368 | 0.1535 | 0.0685 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 12 | 20.0000 | 24.0000 | 21.0000 | 20.0000 | 20.00 | 20.0000 | 6.0000 |
| 13 | 0.0545 | 0.0440 | 0.0524 | -0.1949 | 0.45 | 0.0547 | 0.6072 |
| 14 | -0.0778 | 0.2278 | -0.0074 | -0.2933 | 0.27 | -0.0350 | 0.4115 |
| 15 | -0.0115 | 0.1403 | 0.0233 | -0.2520 | 0.37 | 0.0102 | 0.5504 |
| 16 | -0.2258 | -0.2793 | -0.0515 | -0.3637 | 0.37 | -0.2410 | 0.7281 |
| 17 | -0.1929 | -0.1481 | -0.0623 | -0.3623 | 0.36 | -0.2722 | 0.6734 |
| 18 | -0.0039 | 0.4111 | -0.0196 | 0.0445 | 0.21 | -0.2373 | -0.3297 |
| 19 | 3.0000 | 78.6875 | 2.7565 | 1.2316 | 1183.89 | 11.8976 | 7.6050 |
| 20 | 3.1623 | 17.1634 | 1.2521 | 0.6212 | 481.64 | 9.8408 | 7.7415 |
| 21 | 19.0000 | 24.0000 | 21.0000 | 21.0000 | 18.00 | 21.0000 | 10.0000 |
| 22 | 0.1358 | -0.0270 | 0.0005 | 0.1588 | 0.54 | 0.3953 | -0.1143 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 12 | 20.0000 | 6.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 13 | -0.0617 | 0.5660 | 0.611 | -0.6402 | 0.8901 | 0.0954 | -0.0345 |
| 14 | -0.0195 | 0.2348 | 0.675 | -0.5377 | 0.9671 | -0.0606 | -0.0666 |
| 15 | -0.0419 | 0.4478 | 0.664 | -0.6079 | 0.9585 | 0.0160 | -0.0524 |
| 16 | -0.1777 | 0.5858 | -0.025 | -0.2572 | 0.1287 | 0.4398 | -0.1624 |
| 17 | -0.2476 | 0.5392 | -0.036 | -0.2723 | 0.1715 | 0.4351 | -0.0951 |
| 18 | -0.2159 | -0.2858 | -0.137 | -0.0640 | 0.0132 | 0.2841 | -0.3245 |
| 19 | 4.8833 | 2.9950 | 92.892 | 5.4464 | 0.1845 | 0.9692 | 2.4043 |
| 20 | 5.4227 | 3.2609 | 10.623 | 1.5135 | 0.1060 | 0.5843 | 2.9925 |
| 21 | 21.0000 | 10.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 23.0000 |
| 22 | 0.4280 | 0.2524 | 0.661 | 0.1136 | 0.2999 | 0.1110 | 0.0106 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 12 | 24.0000 | 22.000 | 24.00 | 24.000 | 23.0000 | 17.0000 |
| 13 | 0.0748 | 0.127 | 0.49 | 0.012 | -0.0501 | 0.6310 |
| 14 | 0.0815 | 0.081 | 0.41 | -0.053 | -0.0530 | 0.6172 |
| 15 | 0.0807 | 0.107 | 0.46 | -0.021 | -0.0534 | 0.6425 |
| 16 | -0.0242 | -0.077 | 0.20 | 0.016 | -0.0818 | 0.3168 |
| 17 | -0.0016 | -0.151 | 0.26 | -0.006 | -0.0352 | 0.3622 |
| 18 | 0.1393 | -0.124 | 0.40 | -0.165 | -0.3448 | -0.3253 |
| 19 | 17.9981 | 103.688 | 1355.63 | 262.507 | 26.9364 | 8.0333 |
| 20 | 20.0639 | 70.890 | 323.58 | 142.904 | 36.9810 | 0.3094 |
| 21 | 24.0000 | 24.000 | 24.00 | 24.000 | 23.0000 | 18.0000 |
| 22 | -0.0953 | 0.230 | 0.33 | -0.062 | -0.0178 | -0.3674 |

APPENDIX C. -- Continued (Metabolism Variables).

*** METABOLISM VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 23 | 3 | CORR | OWMETBOT | 0.2016 | 0.0804 | 0.1738 | 0.2706 |
| 24 | 3 | CORR | OWMETAVG | 0.1778 | 0.1297 | 0.1983 | 0.2104 |
| 25 | 3 | CORR | LDMET_L | 0.5416 | 0.5503 | 0.3486 | 0.3086 |
| 26 | 3 | CORR | LDMET_M2 | 0.4749 | 0.4804 | 0.2939 | 0.2549 |
| 27 | 3 | CORR | DOME_MET | -0.1826 | -0.1140 | 0.1615 | 0.1163 |
| 28 | 4 | MEAN | | 14.2708 | 11.2396 | 27.9625 | 28.3187 |
| 29 | 4 | STD | | 12.0774 | 11.8346 | 4.0277 | 4.2079 |
| 30 | 4 | N | | 24.0000 | 24.0000 | 24.0000 | 24.0000 |
| 31 | 4 | CORR | OWMETSRF | -0.0212 | 0.2747 | -0.0925 | -0.2448 |
| 32 | 4 | CORR | OWMETBOT | 0.1004 | 0.1009 | 0.2362 | 0.1976 |
| 33 | 4 | CORR | OWMETAVG | 0.0310 | 0.2768 | 0.0378 | -0.1074 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 23 | -0.1002 | -0.0003 | -0.3641 | -0.0217 | 0.19 | 0.0988 | 0.1645 |
| 24 | 0.0156 | -0.0158 | -0.2296 | 0.0778 | 0.41 | 0.2903 | 0.0074 |
| 25 | 0.3773 | -0.3440 | -0.0869 | -0.0227 | 0.44 | 0.7680 | 0.3613 |
| 26 | 0.3784 | -0.1965 | -0.0364 | -0.1834 | 0.33 | 0.4856 | 0.2500 |
| 27 | 0.3549 | 0.5658 | 0.6225 | 0.0618 | -0.47 | -0.1361 | -0.6142 |
| 28 | 2.5238 | 80.1458 | 2.7879 | 1.1457 | 1312.94 | 7.3167 | 6.0823 |
| 29 | 3.4296 | 12.6418 | 1.3443 | 0.3505 | 503.31 | 8.7006 | 8.7078 |
| 30 | 21.0000 | 24.0000 | 19.0000 | 20.0000 | 17.00 | 21.0000 | 11.0000 |
| 31 | 0.2785 | -0.0190 | 0.0380 | 0.1220 | -0.00 | 0.2502 | 0.1964 |
| 32 | -0.0310 | 0.3552 | -0.0687 | 0.2341 | 0.01 | -0.1099 | -0.6652 |
| 33 | 0.2161 | 0.1564 | -0.0006 | 0.2134 | 0.00 | 0.1543 | -0.1596 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 23 | 0.0107 | -0.3136 | 0.091 | -0.3890 | 0.9299 | 0.3799 | 0.0491 |
| 24 | 0.2535 | 0.0102 | 0.439 | -0.1802 | 0.7602 | 0.3046 | 0.0376 |
| 25 | 0.5515 | 0.0066 | 0.320 | -0.1497 | 0.0721 | 0.4138 | -0.2624 |
| 26 | 0.4956 | 0.1049 | 0.344 | -0.0821 | 0.0226 | 0.3330 | -0.2772 |
| 27 | -0.1186 | -0.2413 | 0.055 | 0.0579 | -0.1975 | -0.2711 | 0.3392 |
| 28 | 3.3333 | 3.8909 | 81.178 | 4.9278 | 0.1697 | 1.1152 | 2.5208 |
| 29 | 4.0014 | 12.4942 | 21.707 | 1.8384 | 0.1456 | 0.8722 | 2.7318 |
| 30 | 21.0000 | 11.0000 | 21.000 | 21.0000 | 21.0000 | 18.0000 | 24.0000 |
| 31 | 0.0565 | 0.3939 | 0.659 | 0.4601 | 0.1469 | -0.0655 | 0.0012 |
| 32 | -0.0830 | -0.6719 | 0.463 | -0.0037 | 0.7896 | 0.0644 | 0.3657 |
| 33 | 0.0066 | 0.0143 | 0.771 | 0.3800 | 0.5047 | -0.0243 | 0.1783 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 23 | 0.3631 | 0.056 | 0.07 | -0.374 | -0.0569 | -0.3338 |
| 24 | 0.1744 | 0.168 | 0.24 | -0.272 | -0.0467 | -0.4165 |
| 25 | 0.0674 | -0.326 | 0.16 | -0.375 | -0.2978 | 0.1533 |
| 26 | 0.0422 | -0.387 | 0.11 | -0.343 | -0.3216 | 0.2420 |
| 27 | -0.0993 | -0.056 | 0.37 | 0.323 | 0.3172 | 0.2093 |
| 28 | 19.5938 | 125.438 | 1501.46 | 287.413 | 30.3689 | 8.0150 |
| 29 | 16.5721 | 99.873 | 674.94 | 233.460 | 56.3616 | 0.3496 |
| 30 | 24.0000 | 24.000 | 24.00 | 24.000 | 24.0000 | 18.0000 |
| 31 | -0.4498 | -0.102 | 0.03 | 0.230 | 0.0760 | -0.0913 |
| 32 | 0.0289 | -0.370 | -0.04 | -0.012 | 0.1384 | -0.1245 |
| 33 | -0.3593 | -0.263 | 0.01 | 0.185 | 0.1302 | -0.1508 |



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APPENDIX C. -- Continued (Metabolism Variables).

*** METABOLISM VARIABLES ***

| OBS | LOCATION | _TYPE_ | _NAME_ | SAL_BOT | SAL_SRF | WTMP_SRF | WTMP_BOT |
|---|---|---|---|---|---|---|---|
| 34 | 4 | CORR | LDMET_L | 0.5652 | 0.6282 | 0.3892 | 0.3445 |
| 35 | 4 | CORR | LDMET_M2 | 0.5892 | 0.6469 | 0.4053 | 0.3605 |
| 36 | 4 | CORR | DOME_MET | -0.0508 | -0.0099 | -0.1041 | -0.1676 |

| OBS | DPTH_CHN | DPTH_AVG | WNDSPD | LTEXCOEF | LT_SRF | TSS_SRF | TSSSTRAT |
|---|---|---|---|---|---|---|---|
| 34 | -0.1407 | -0.0781 | -0.0668 | 0.0756 | -0.15 | 0.6320 | 0.0260 |
| 35 | -0.1173 | 0.0252 | -0.0589 | 0.1020 | -0.16 | 0.5534 | -0.0044 |
| 36 | -0.1063 | 0.3629 | 0.1498 | 0.2291 | -0.22 | 0.2543 | 0.0792 |

| OBS | SOM_SRF | SOMSTRAT | DO_PCT_L | EARLY_DO | DO_CHNG | BOD_SRF | ORTH_PO4 |
|---|---|---|---|---|---|---|---|
| 34 | 0.4794 | -0.0559 | 0.088 | -0.1781 | 0.0714 | -0.0486 | -0.1444 |
| 35 | 0.4140 | -0.0504 | 0.067 | -0.2309 | 0.1304 | -0.0850 | -0.0992 |
| 36 | 0.0678 | 0.0689 | -0.158 | -0.0855 | -0.0449 | -0.4231 | 0.3046 |

| OBS | TOTAL_P | NH4 | TOTAL_N | NP_RATIO | PO4_TP | PH |
|---|---|---|---|---|---|---|
| 34 | 0.1083 | -0.135 | 0.08 | -0.028 | 0.0672 | 0.1623 |
| 35 | 0.0918 | -0.190 | 0.06 | -0.030 | 0.0846 | 0.1581 |
| 36 | -0.3431 | -0.082 | 0.01 | 0.231 | 0.1237 | 0.4014 |



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Appendix 8. Vegetation, Water Quality, Hydrology, Estuarine Salinity and Productivity in C-111 basin.

Hydrology - Jim Milleson

Vegetation - Peter David

Water Quality - David Swift

Estuarine Salinity & Productivity - Dan Haunert



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## SECTION I - HYDROLOGY

### INTRODUCTION

C-111 is the southernmost canal of the Central and South Florida Flood Control Project, designed and constructed by the U.S. Army Corps of Engineers (COE), and operated by the South Florida Water Management District (District). Located in extreme southeastern Dade County, C-111 provides a gravity outlet for stormwater runoff from an approximately 100 sq mi drainage basin, the northern portion of which is dominated by intensive agricultural development. C-111 is also the final leg of the South Dade Conveyance System, which provides a means to deliver water to Everglades National Park (ENP) at Taylor Slough and the Eastern Panhandle, in compliance with the minimum water delivery schedule.

Just south of the agriculturally developed area, southwest of Homestead and Florida City, C-111 is joined by C-111E, and follows a course southward, southeastward and southward again, bisecting an extensive marl wetland prairie before its terminus at Manatee Bay.

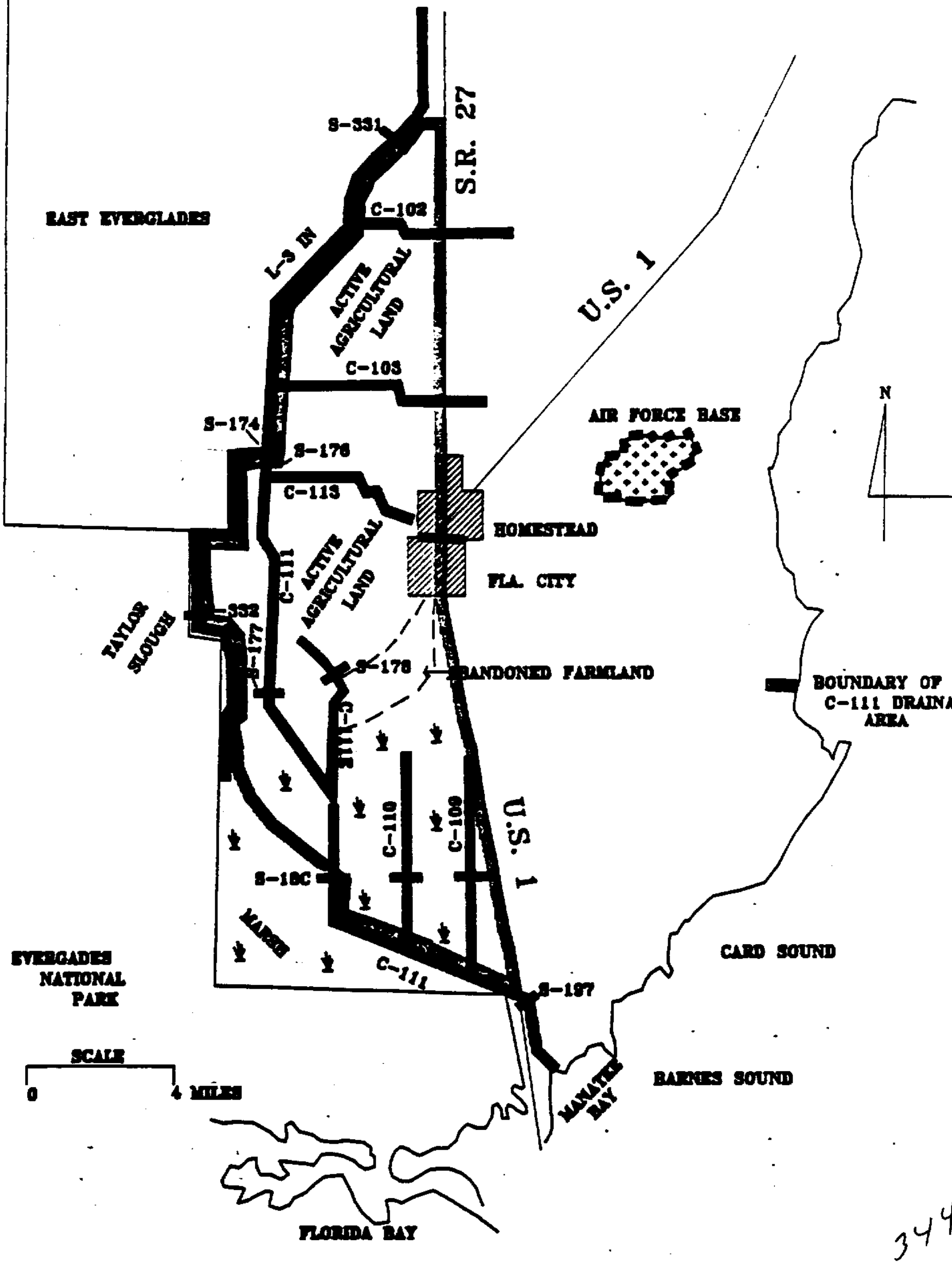
Constructed in the late 1960s, C-111 was only part of a more extensive system of canals and structures planned to enable the development of low lying coastal areas in south Dade County. Changes in the economic growth forecasts for the area, coupled with severe drought conditions in 1971, led to the COE decision to discontinue much of the remainder of the system. Consequently, the outlet for C-111 canal was never completed. To avoid salt water intrusion up C-111 into the freshwater wetlands north of ENP panhandle, a culvert structure and a temporary earthen plug were installed just east of U.S. Highway 1.

Water flows from C-111 and C-111E converge just north of structure S-18C. Under normal rainfall conditions, after water passes through S-18C it can be dispersed over a five mile wide segment of marsh by flowing through 55 gaps, each 100 ft in width, in the south spoil bank. Flow can also be discharged through the culvert structure, S-197, to Manatee Bay, up to a maximum rate of 550 cfs. During large storm events, the earthern plug adjacent to S-197 can be removed to maximize discharge to Manatee Bay.

A number of environmental concerns in the areas adjacent to and downstream of C-111 have precipitated a re-examination of the potential impacts of this portion of the water control system. The foremost concern, voiced by conservationists and sport fishing interests, centered around declining fish catches and productivity in northeast Florida Bay, allegedly associated with increased salinities due to reduction of freshwater inflows. Other adverse environmental conditions potentially related to C-111 included: excessive freshwater discharges to Manatee Bay during severe storms; overdrainage and shortened hydroperiods in marshes adjacent to the canal; ponding and prolonged hydroperiods in marshes impounded by canal levees; disruption and redirection of natural sheet flow patterns over the marsh. Each of these conditions is potentially aggravated by changes in surface and groundwater flow rates and patterns due to extensive upstream land use modifications.

Based primarily on these concerns, and the knowledge that agricultural land uses in the area were changing from seasonal winter vegetables to year round crops requiring more intensive flood control capabilities, the District requested the COE to

FIG. 1: C-111 DRAINAGE AREA, LAND USES AND SURROUNDING FEATURES

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network in the area, beginning in 1985. A District sponsored symposium in February 1985, focused on the water related issues of the C-111 basin, examined the alternatives under consideration by the COE, and provided general agreement that basic research was required in several areas before the alternatives could be thoroughly evaluated. The District and ENP each embarked on two year programs designed to increase background understanding of the relationships of various environmental components in the C-111 area to freshwater flows and hydrology.

Specific goals of District studies include the following:

HYDROLOGY: Establish a network of water level and groundwater gauges within the project area to evaluate the groundwater/surface water interactions. Update existing hydrological information on canal levels, flows, and rainfall.

WATER QUALITY: Characterize spatial and temporal trends in water quality parameters which may influence the ecology of the area, including marsh and canal habitats, and nearshore areas of northeast Florida Bay and Manatee Bay.

PLANT COMMUNITIES: Characterize marsh plant communities, including both microflora (i.e. periphyton) and macroflora in the various areas surrounding C-111 as may be influenced by different water level or water quality regimes.

MARSH PRODUCTIVITY: Characterize primary productivity of periphyton communities in terms of biomass and chlorophyll a production, and community metabolism in relation to water quality and hydrologic differences. Document the species composition and abundance of forage organisms such as small fish, crayfish and prawns in marshes surrounding C-111.

ESTUARINE STUDIES: Describe habitat characteristics of Manatee Bay which may be influenced by changes in freshwater inflow regimes. Document the curre[illegible] salinity trends in Manatee Bay in relation to present C-111 management practices for the study period. Compare and contrast productivity of Manatee Bay, as measured by copepod density, with nearshore habitats of northeast Florida Bay.

Results of District investigations are presented in three main sections. Section I concentrate on the Hydrology of the area; Section II will summarize information on the predominantly freshwater aspects of the system, including water quality transects into the estuarine areas; Section III stresses the work done in Manatee Bay and Northeast Florida Bay.

## METHODS

### HYDROLOGY

Information on surface water hydrology for the C-111 study area was required for both the canal/structural component of the system and for the adjacent wetland marshes. Information was compiled from the following existing water level recorders for the canal system:

S-18C headwater stage
S-197 headwater stage
S-18C discharge in cfs
S-197 discharge in cfs

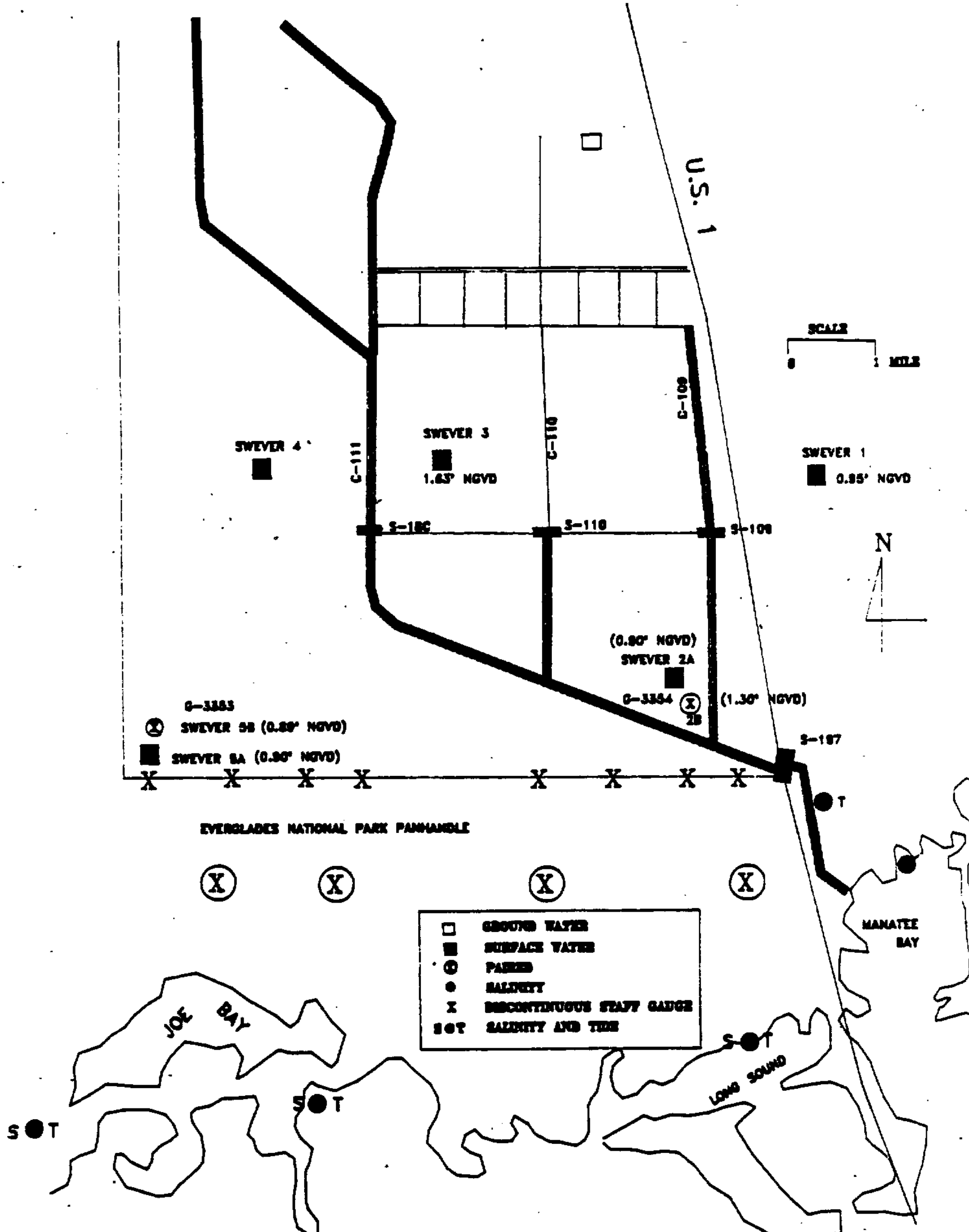


FIG. 2: HYDROLOGIC NETWORK

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was made with adjacent residential and agricultural interests to control groundwater stages at pre-determined levels by maintaining low stages in the L-31N borrow canal. This action results in a considerable amount of groundwater being passed southward through the canal, and eventually ending up as flow through S-18C. Table 2 presents a summary of annual flow through S-18C in relation to rainfall at the structure for the period 1977-1987.

TABLE 2: ANNUAL FLOW VERSUS RAINFALL AT S-18C

| YEAR | S-18C flow (ac-ft x 1000) | S-18C rainfall (inches) |
|---|---|---|
| 1977 | 44.96 | 45.55 |
| 1978 | 51.09 | 58.84 |
| 1979 | 44.17 | 43.51 |
| 1980 | 67.31 | 44.70 |
| 1981 | 132.93 | 44.00 |
| 1982 | 99.49 | 47.51 |
| 1983 | 319.89 | 53.21 |
| 1984 | 139.41 | 33.33 |
| 1985 | 189.23 | 49.70 |
| 1986 | 212.45 | 33.91 |
| 1987 | 191.51 | 39.56 |

This clearly shows a change in the annual flow regime to which the C-111 area has been subjected to since the early 1980's, and throughout the duration of the two year study period from October 1985 through September 1987.

Flow is passed through the S-18C structure whenever the headwater level increases above 2.30 ft NGVD. After water is discharged at S-18C, it is dispersed in basically four ways:

1) as flow through culvert openings at S-197 to tidewater in Manatee Bay/ Barnes Sound (and in unusual circumstances as direct discharge when the earthen plug is removed),

2) as overland flow southward through the 55 gaps in the spoil bank on the south side of C-111, towards ENP panhandle and Northeast Florida Bay,

3) flow northward through nine culverts in the north C-111 spoil bank when the stage in the canal exceeds 2.0 ft NGVD (the control board setting) and a lower water level occurs in the marsh to the north,

4) as groundwater recharge into the limestone aquifer.

A simple water budget (Table 3) can be prepared by subtracting measured flows at S-197 from S-18C to yield the amount of water which is distributed in the remaining three ways. Further refinement of that is beyond the scope of these investigations, however it is suspected that some simple assumptions could be made to estimate these distributions.

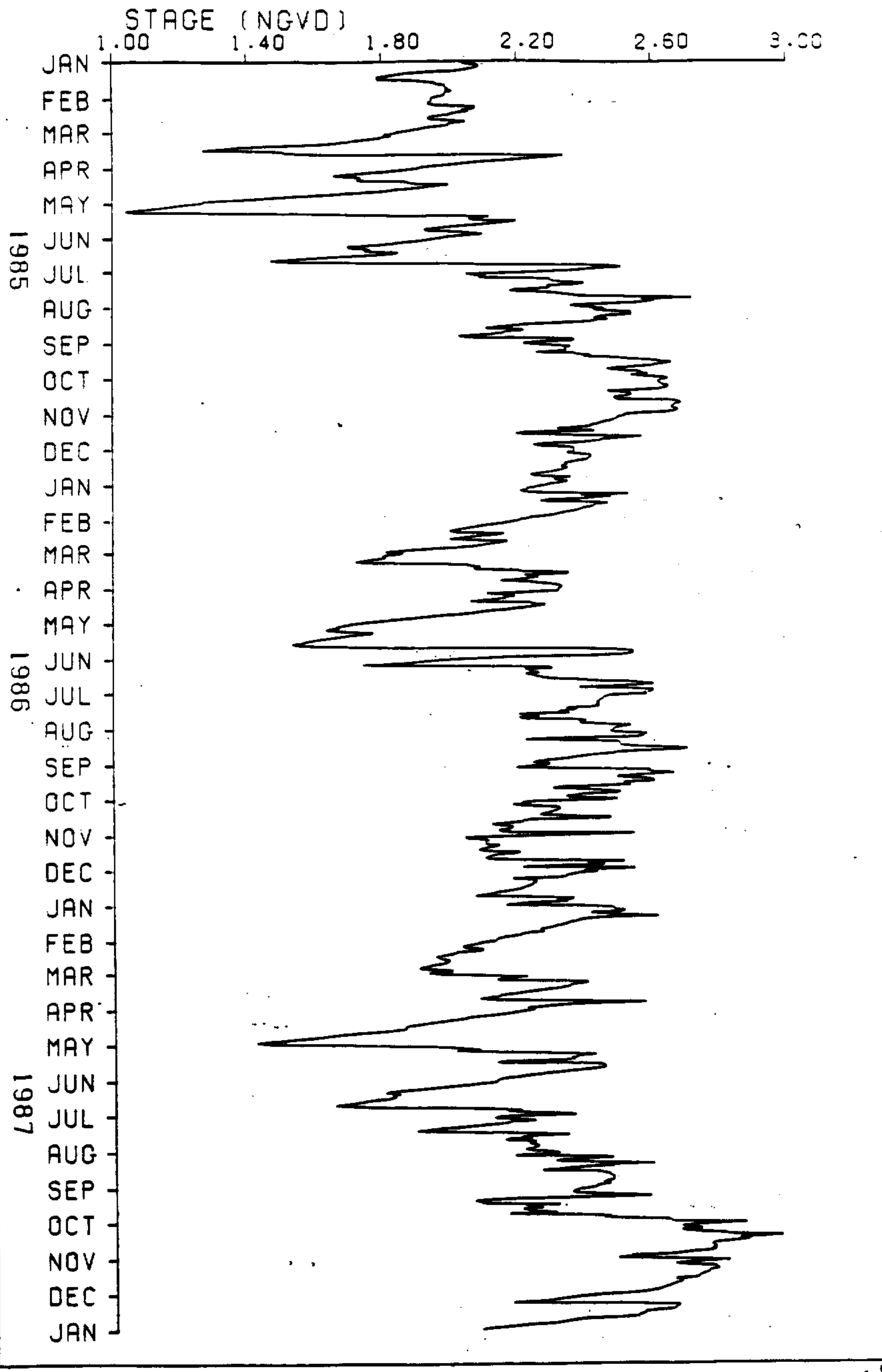


FIG 3. HYDROGRAPH FOR STAGE S18C (1985-1987)

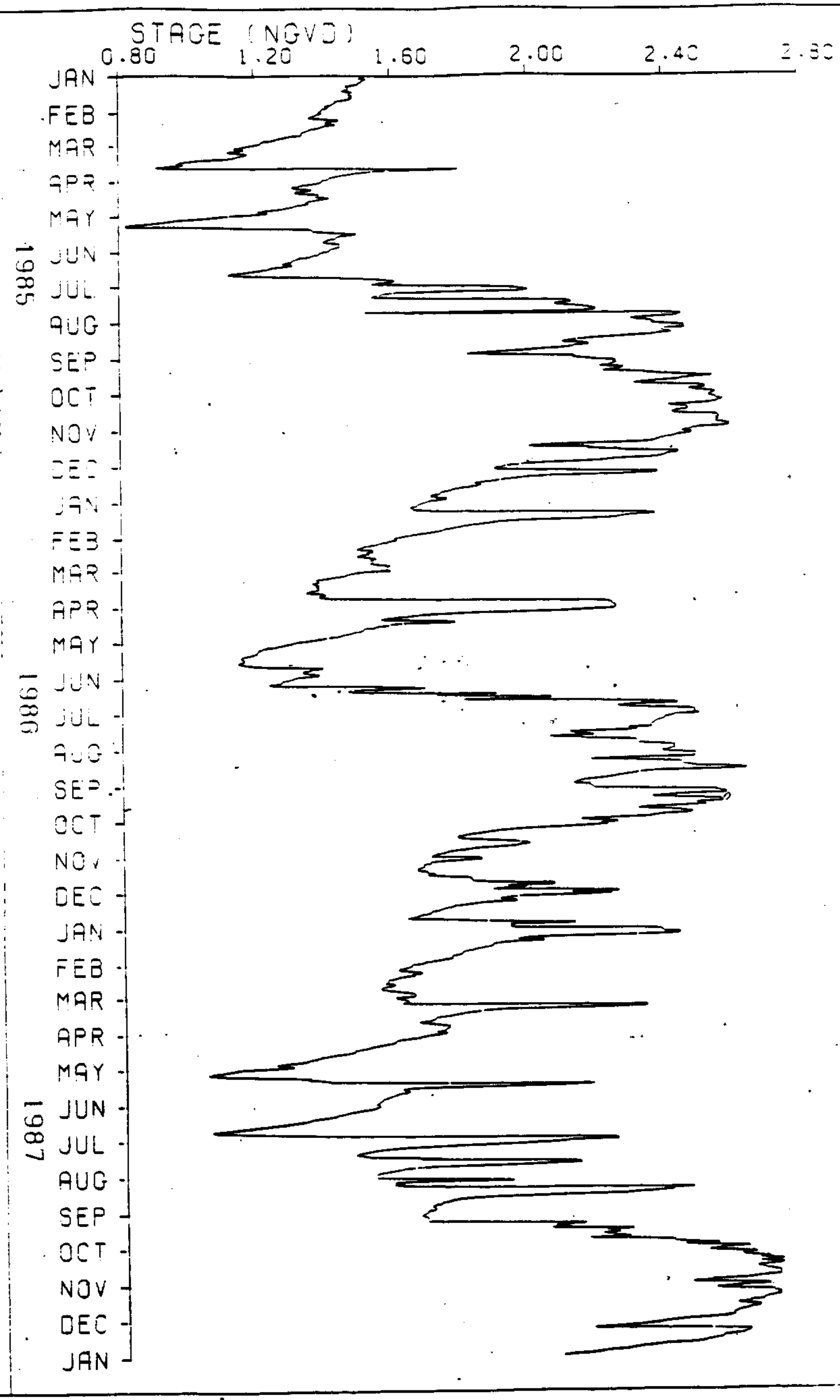


FIG 4. HYDROGRAPH FOR STAGE S197 (1985-1987)

Maximum stage at SWEVER 2 was 2.54 ft in October 1986; minimum was 0.09 ft May 1987. Average water depth for the wet season months (June-October) was 1.06 ft (12.7 in). Water depths in the 1986 wet season were greater (2.08 ft) than in 1987 (1.71 ft). The marsh at SWEVER 2A was inundated for the entire duration of the study period. Figure 6 shows the SWEVER 2A hydrograph.

SWEVER 3

SWEVER 3 is the second gauge located in the marsh impounded by the C-111 levee and U.S.1. This station is situated between C-110 and C-111, about 1.2 miles northeast of S-18C. The ground elevation at SWEVER 3 is 1.60 ft NGVD. A maximum stage of 2.56 ft occurred in October 1985, while the minimum of record was 0.81 ft NGVD in May 1986. Average wet season water depth was only 0.51 ft (ie. 2.11 ft), with water somewhat deeper in 1986 than 1987. The marsh at SWEVER 3 dried completely for 48 days in 1986 and 29 days in 1987. Figure 7 shows the hydrograph for SWEVER 3.

SWEVER 4

Located to the west of C-111, about 0.8 miles north north west of S-18C, this station occupies the highest ground elevation of the five gauges. There has been some problems in establishing the actual elevation, with two different values being reported of 1.6 ft and 2.6 ft NGVD. Based on field observations and water depth measurements compared with gauge height readings, a ground elevation of 2.00 ft NGVD was used for SWEVER 4.

A maximum stage of 2.55 ft occurred in August 1986 (2.54 in October 1985) while the minimum of record was 1.08 ft in April 1987. The average wet season stage for the months June to October was identical to SWEVER 3, 2.11 ft, providing for an average wet season depth of only 0.11 ft (1.3 in). Water levels at SWEVER 4 were below ground for extended periods of time, from February 1 until June 16, 1986; from October 23 until December 23, 1986; January 26 until March 6, 1987; and the majority of the period from March 16 to August 6, 1987. Figure 8 shows the hydrograph for SWEVER 4.

SWEVER 5

This is the second location which combines a surface water recorder (SWEVER 5A) with a paired surface and groundwater station (SWEVER 5B and G-3353). SWEVER 5 is located 4 miles southwest of S-18C, at the point where the boundary for ENP panhandle turns to the north. SWEVER 5 is away from the direct influence of C-111, in terms of flow diversion or impoundment by the levees. SWEVER 5A and 5B stages do not track as closely as 2A and 2B. There is generally a 0.10 ft difference between the gauges, with 5B being higher. However, during low periods, 5B tends to "bottom out" at 1.06-1.02 ft NGVD level. Stages for SWEVER 5A were estimated from 5B for a data gap period from June 11 to July 16, 1986.

Land elevation at SWEVER 5A is 0.90 ft NGVD. The maximum stage at this gauge was 1.87 ft in November 1985; a minimum of 0.01 ft was recorded on July 14, 1987. Average wet season water depth was only 0.23 ft (1.13 ft NGVD), with 1987 wet season levels considerably lower than 1986. The marsh at SWEVER 5A was dry for 52 days in 1986 from April 17 until June 7; and for 78 days in 1987 (April 19-May 18 and May 30-July 16). Figure 9 shows the hydrograph for SWEVER 5A.

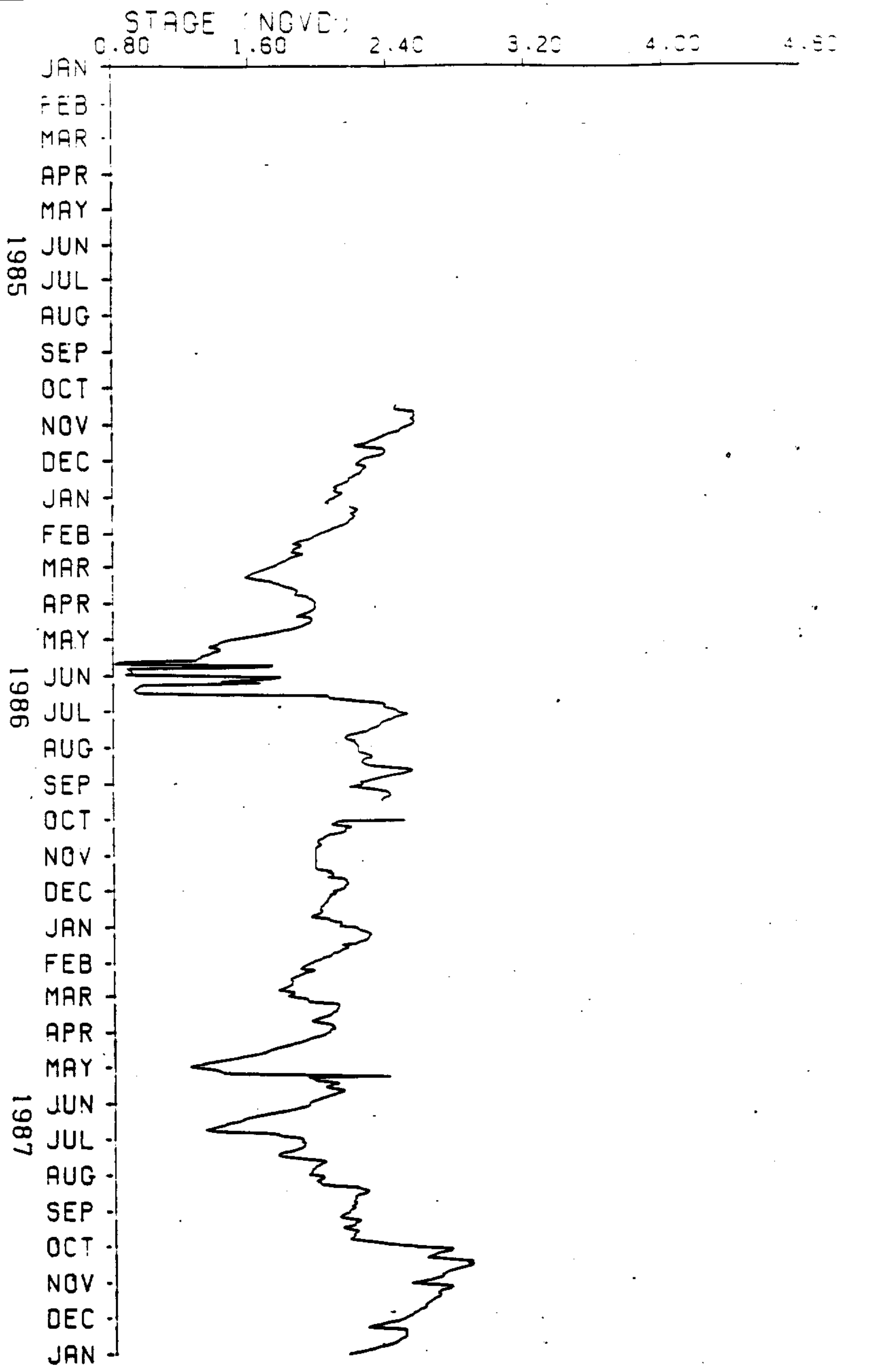


FIG 7. HYDROGRAPH FOR STAGE SWFVER3 (1985-1987

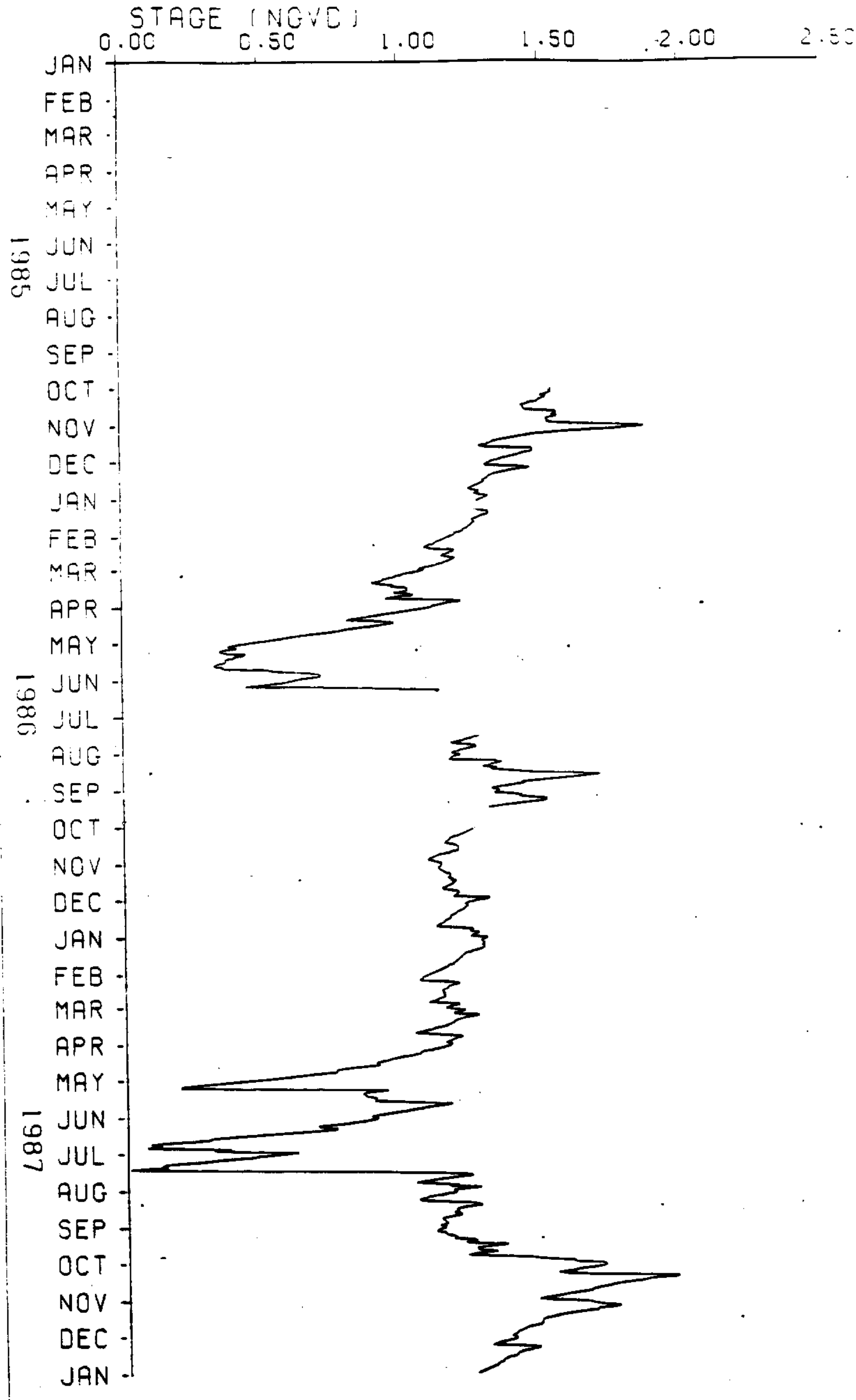


FIG. 9 HYDROGRAPH FOR STAGE SWEVERSA

Table 4 summarizes the hydrologic charactristics of the five marsh stations.

COMPARISONS AMONG WATER LEVEL GAUGES

1) SWEVER 1, located east of U.S. 1, was compared with SWEVER 2A, located in the impounded area just west of U. S. 1. Periods of seasonal high and low stages compared favorably for these two stations with similar land elevations, but the magnitude of the peaks were substantially lower at SWEVER 1 by 0.6 ft in many instances. This difference was undoubtedly caused in part by the impounding function of the C-111 levee and canal which prevented surface waters from moving southward.

2) Hydrographs for SWEVER 2A and SWEVER 3, both located within the impounded area, were similar in shape, although a ground elevation difference of 0.7 ft exists between the two sites. SWEVER 3 stages were generally 0.1 to 0.3 feet higher than SWEVER 2B, suggesting a slow overland flow of surface waters southward, even within the impounded area.

3) Hydrographs for SWEVER 3 and SWEVER 4 were the most similar of the surface stations compared, especially for the times when the stage at SWEVER 4 exceeded 2.0 ft NGVD (ground level). These two stations are located on opposite sides of C-111 canal, but seem to be strongly influenced by stages held in the canal: S-18C headwater stage was typically 0.1 to 0.2 ft above these two stations

4) The shape of the SWEVER 5A hydrograph was very similar to SWEVER 4, reflecting both the relative magnitudes of the high and low peaks, as well as the rates of recessions and declines, regardless of whether stages were above ground at SWEVER 5A (0.9 ft NGVD) or not. Water stages at SWEVER 5A were consistently 0.8 to 1.0 ft below SWEVER 4, suggesting a southward flow of surface and ground water on the west side of C-111.

5) Paired surface water and ground water stations SWEVER 5B/G-3353 and SWEVER 2B/G-3354 were constructed such that the well of the ground water station penetrated through the marl and into the porous limerock below the land surface, whereas the surface station well was purposely installed so the marl was not fully penetrated. The strategy in this well construction was to determine whether the two water level readings were identical, suggesting a direct surface and ground water connection. Consistent differences in water level readings indicates a distinction or separation between the waters, implying that different forces are driving groundwater levels compared with surface water levels. A cursory examination of the SWEVER 5B/G-3353 hydrographs showed the groundwater levels to generally be 0.05 ft above the surface stage, with the difference being more pronounced in the wet season months than in the dry season months. This suggests that ground water is subjected to a driving force or pressure due to recharge from the north.

Differences in ground and surface water level readings at SWEVER 2B/G-3354 were much less pronounced than SWEVER 5B/G-3353. Table 5 shows nearly identical readings throughout the study period indicating that the influence of water levels and water movement from C-111 canal is much greater on both surface water and ground water stages in the adjacent wetlands, which may dominate other influences such as ground water recharge from the north.

## SECTION II - FRESHWATER STUDIES

## METHODS AND MATERIALS

### WATER QUALITY

Thirteen synoptic water quality surveys were conducted on a bimonthly basis by float helicopter from August 1985 - August 1987. During the first year of study, a total of 75 sites were sampled along five separate transects (Figure 10). In August 1986, this network was reduced to 55 sites. These five transect lines correspond to those previously established by Tabb et. al. (1967) with some additional sites established north of C-111 within the impounded area, and east of U.S. Highway 1. Table 6 lists sampling dates.

Surface water samples were collected in clean 500 ml polyethylene bottles, placed on ice and returned to the laboratory for analysis. The following day, samples were shaken, filtered through 0.45 um Millipore membrane filters and analyzed for macro-nutrients ( Total N, NH4, NO3, Total PO4, Ortho PO4), salinity, chloride, alkalinity, and sulfate utilizing Technicon AutoAnalyzer methods.

Major cations (calcium, magnesium, and silicate) were measured less frequently using flame atomic emission. Chemical methods used were either recommended or approved by U.S. Environmental Protection Agency. Due to laboratory equipment problems, measurements of nitrite + nitrate nitrogen from marine waters were made with a Hach Chemical Kit in combination with a Perkin Elmer spectrophotometer during the first four surveys (August 1985-February 1986). Limit of detection for the Hach method was 0.02 mg/l for NO2+NO3, while later analyses using Technicon methodologies were 0.004 mg/l.

Field conductivity measurements were made with a Hydrolab data logger (Model 4041). Field salinity readings were periodically checked against a refractometer (American Optical Corp.) In the laboratory, temperature compensated specific conductivity values were measured using a Radiometer (CDM3) conductivity meter at standard temperature (25 degrees C) and converted to salinity (S) in parts per thousand using the following equations (Hydrolab Corp., 1981):

1) $C = \text{conductivity (umhos/cm)}/1000$

2) if $C < 16$, $S = C \times 0.5625$

3) if $16 < C < 42$, $S = (C-16) \times 0.6923 + 9$

4) if $C > 42$, $S = (C-42) \times 0.7222 + 27$

Water depths were measured at the time of sample collection and correlated with the nearby USGS gaging stations (SWEVER 1-5). Marl soil depths were measured on one survey with a steel probe. Marsh soil chloride content was measured in October 1985 by coring the top six inches of marl soil from each of the stations using a 5.2 cm diameter piston corer. Samples were oven dried at 70 degrees C, and a 10 gram subsample was obtained. The subsample was mixed with 50 ml distilled water and 4 drops Hexametaphosphate dispersing agent, and placed in a wrist action shaker for one hour. The mixed slurry was filtered through #42 filter paper into a beaker. Chloride concentrations were determined from the extracted solution by colorometric

Table ~~5~~ 6. Sample Dates for the various water quality transect sampling and periphyton / water collections.

| Dates | Transect Water Quality sampling | Periphyton/ Water quality sampling | Community Metabolism Studies |
|---|---|---|---|
| 8/14-15/85 | X | | |
| 10/23-24/85 | X | | |
| 12/9-10/85 | X | | |
| 1/21/86 | | X | X |
| 2/6-7/86 | X | | |
| 3/5/86 | | X | X |
| 4/9-10/86 | X | | |
| 4/23-24/86 | | X | X |
| 6/2-3/86 | | X | X |
| 6/10-11/86 | X | | |
| 7/14-15/86 | | X | X |
| 8/5/86 | X | | |
| 9/02/86 | | X | X |
| 9/15/86 | | X | |
| 10/8/86 | X | | |
| 10/28/86 | | X | X |
| 12/2-3/86 | X | X | X |
| 1/6-7/87 | | X | X |
| 2/4-5/87 | X | X | X |
| 4/6-7/87 | X | X | X |
| 5/27-28/87 | X | X | X |
| 7/1/87 | | X | X |
| 8/5-6/87 | X | X | X |
| 9/23-25/87 | | X | X |

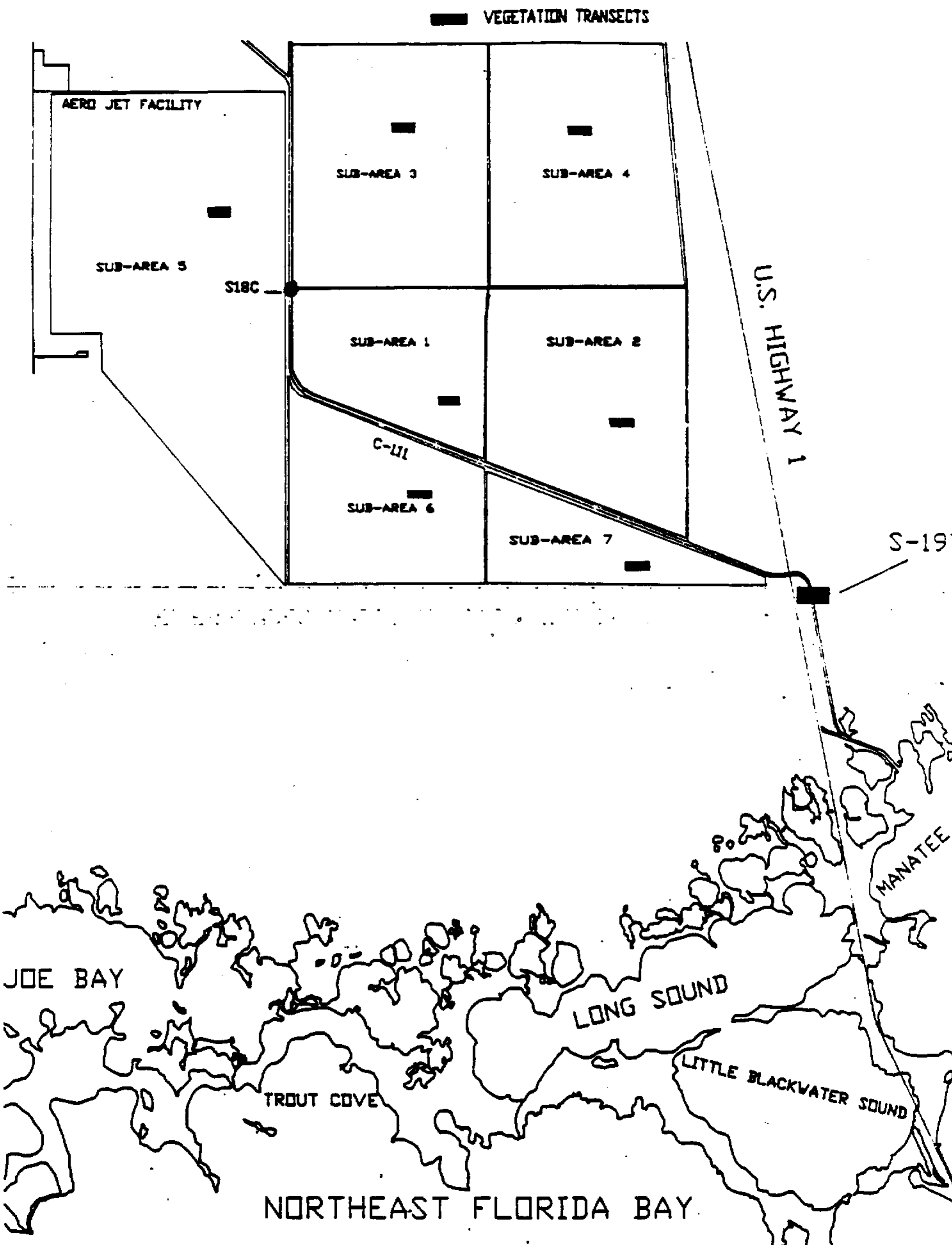
VEGETATION TRANSECTS
AERO JET FACILITY
SUB-AREA 3
SUB-AREA 4
SUB-AREA 5
S18C
SUB-AREA 1
SUB-AREA 2
C-111
SUB-AREA 6
SUB-AREA 7
U.S. HIGHWAY 1
MANATEE
JOE BAY
LONG SOUND
TROUT COVE
LITTLE BLACKWATER SOUND
NORTHEAST FLORIDA BAY

Fig. 11

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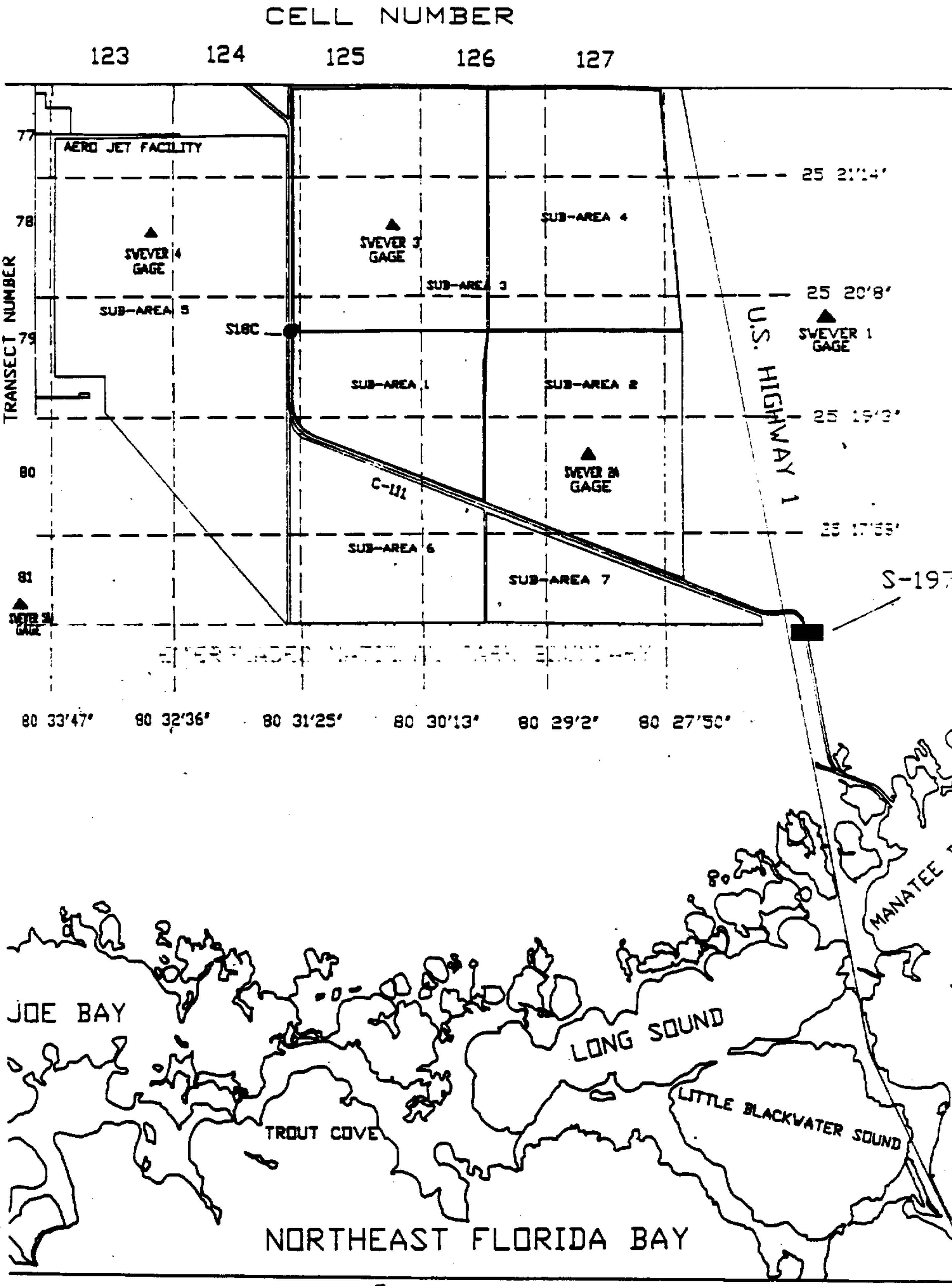
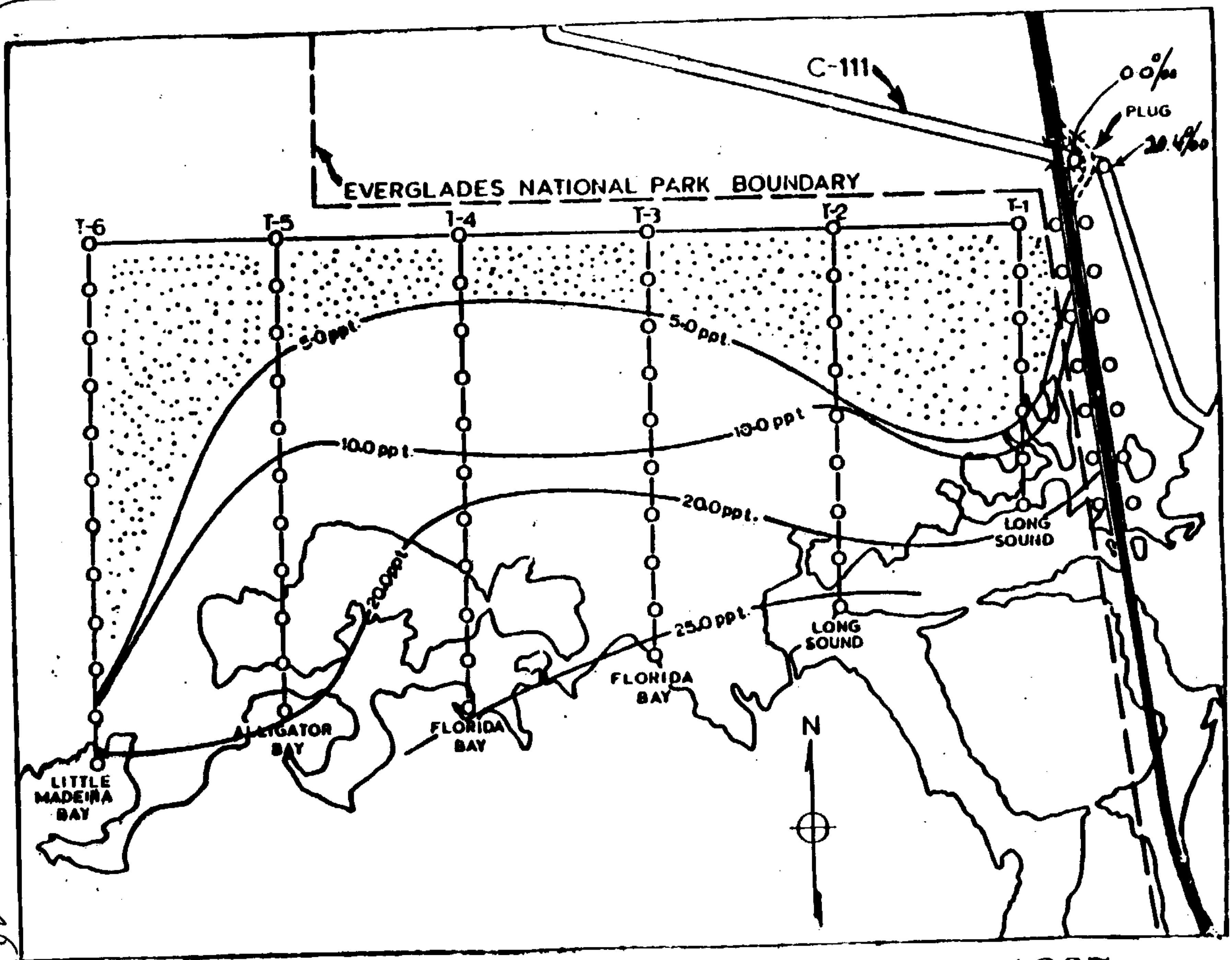

CELL NUMBER
123
124
125
126
127
TRANSECT NUMBER
77
78
79
80
81
AERO JET FACILITY
SWEVER 4 GAGE
SUB-AREA 5
SWEVER 3 GAGE
SUB-AREA 3
SUB-AREA 4
S18C
SUB-AREA 1
SUB-AREA 2
SWEVER 2A GAGE
C-111
SUB-AREA 6
SUB-AREA 7
U.S. HIGHWAY 1
SWEVER 1 GAGE
S-197
25 21'14'
25 20'8'
80 33'47'
80 32'36'
80 31'25'
80 30'13'
80 29'2'
80 27'50'
JOE BAY
LONG SOUND
TROUT COVE
LITTLE BLACKWATER SOUND
NORTHEAST FLORIDA BAY

Fig. 12.

Figure 4




SALINITY DATA FEB 16—MAR 10,1967

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Compared with other major canals which drain south Florida agricultural lands (eg., Miami and Hillsboro canals), surface waters within the C-111 canal contained moderate concentrations of dissolved minerals with relatively low concentrations of phosphorus and nitrogen (Tables 7 and 8). Dominant major ions present were bicarbonate, chloride, calcium and sodium. Specific conductivity (a measure of the total concentration of ions in surface water) within C-111 also exhibited mid-range values averaging 585 umhos/cm.

The high calcium carbonate content of south Florida canals and Everglades marsh surface waters is a result of their close proximity to the highly porous limestone aquifer which underlies the marl soils characteristic of the region. As rainfall and runoff from the C-111 canal fluctuate seasonally, concentrations of these dissolved minerals respond accordingly; wet season concentrations are generally lower than the dry season due to dilution by rainfall while high evapotranspiration rates concentrate minerals during the dry season (Figure 15).

In comparison to canals which drain the northern Everglades Agricultural Area (EAA) located south of Lake Okeechobee (Table 7), average total phosphorus concentrations within the C-111 canal at S-18C were considerably (1/3) lower. From 1983-1986 total phosphorus levels at S-18C ranged from less than 0.004 to 0.026 mg/l with an annual average concentration of 0.007 mg/l. From 1985-1987, highest total phosphorus concentrations within C-111 occurred near the end of the dry season, June 1986 and April 1987 (Figure 16). Average annual total phosphorus and orthophosphorus concentrations within the C-111 canal were not significantly different than phosphorus concentrations experienced within adjacent freshwater sawgrass wetlands and other regions of the Everglades (Table 9).

Mean annual total phosphorus concentrations in most uncontaminated surface waters range from 0.010 to 0.050 mg/l (Wetzel,1975). Vollenweider (1968) states that total phosphorus concentrations generally increase with ecosystem productivity and that aquatic ecosystems (lakes) exhibiting less than 0.010 mg/l total phosphorus are usually classified as oligotrophic or nutrient deficient. Using the above criteria, surface waters within the C-111 canal and adjacent wetland marshes may be described as oligotrophic with respect to the availability of phosphorus within both systems.

Inorganic nitrogen concentrations within south Florida lakes, canals and marshes occur principally in three forms as ammonia ($NH_4$), nitrate ($NO_3$) and nitrite ($NO_2$). Inorganic nitrogen is considered the most readily available form for uptake and subsequent growth by aquatic plants and were therefore a major focus of this study.

Average inorganic nitrogen levels within C-111 were also low in comparison to EAA drainage canals (Table 8). However, annual average inorganic nitrogen concentrations within the canal were higher (mean = 0.23 mg/l) than surrounding adjacent sawgrass wetlands where mean annual values ranged between 0.08 - 0.14 mg/l (Figure 17, Table 9). Inorganic nitrogen concentrations showed no clear seasonal pattern but were highly correlated with increased flow rates through S-18C ($r = .861$) and increased rainfall activity within the basin.

FRESHWATER SAWGRASS WETLANDS:

Surface waters within sawgrass marshes located immediately north, west and extending a short distance south to the boundary of Everglades National Park

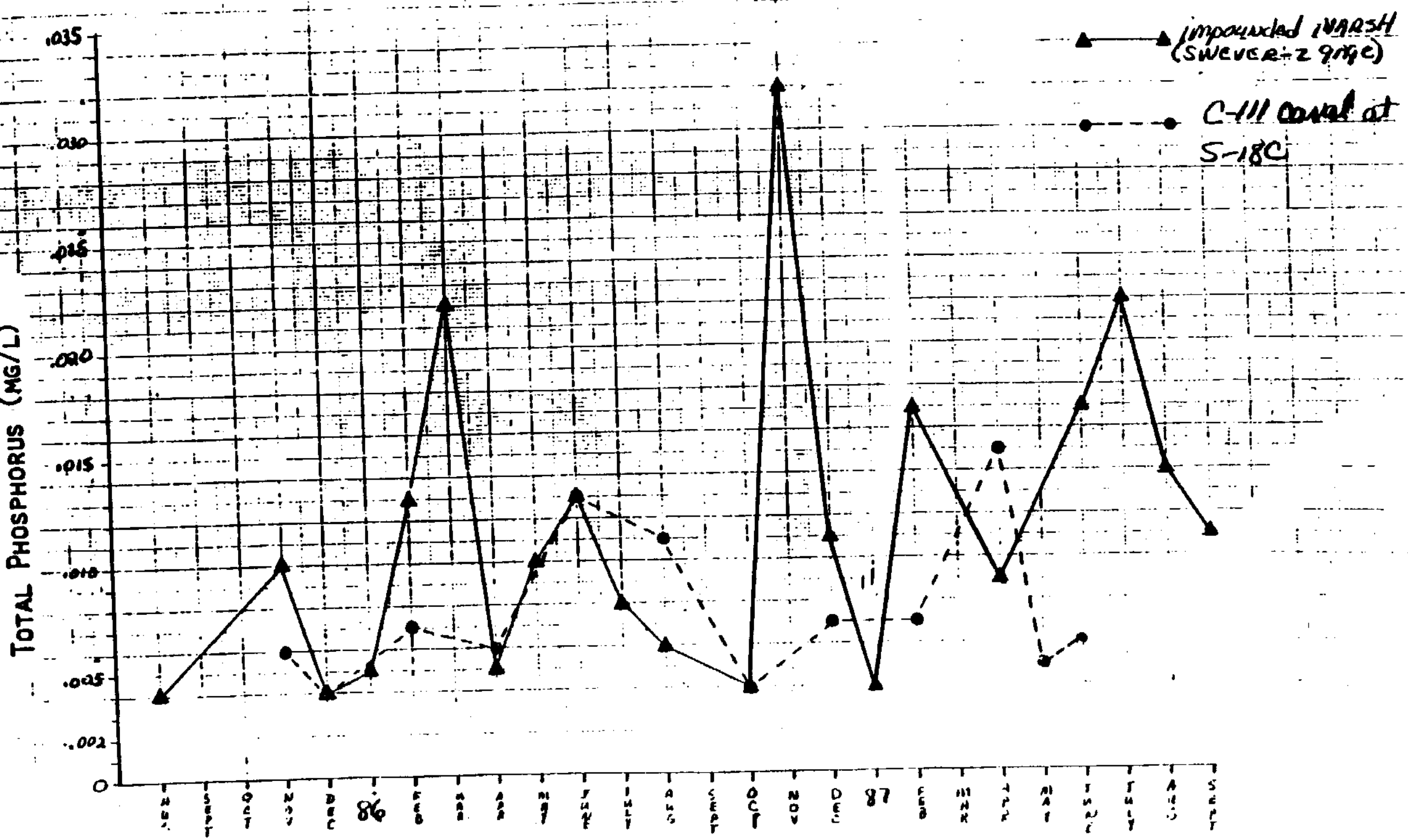


FIGURE SEASONAL TOTAL PHOSPHORUS CONCENTRATIONS WITHIN THE C-111 CANAL AND AT THE SWEVEP-2 GAGE, 8/85-8/87

38

360

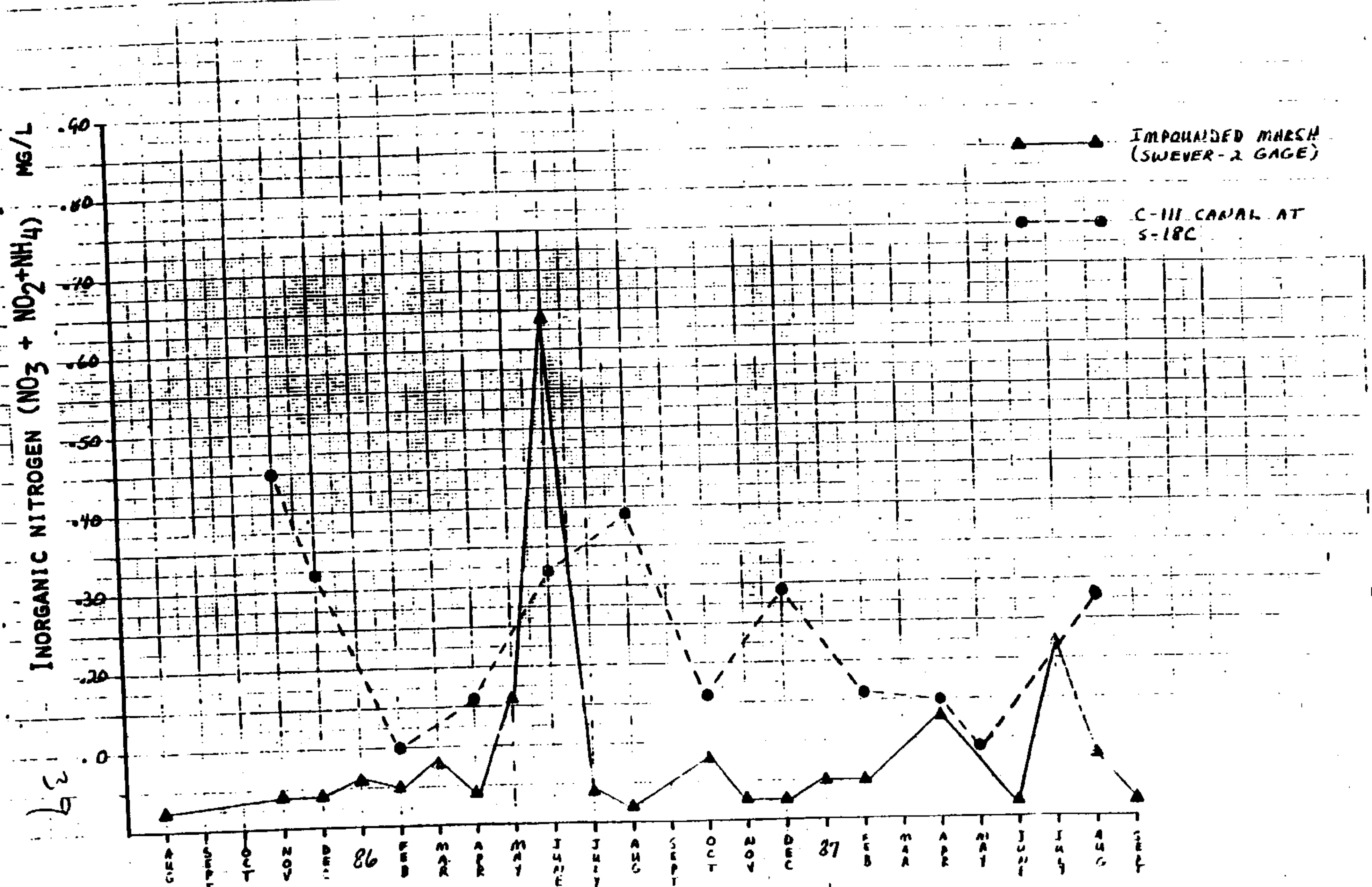


FIGURE 17. SEASONAL CONCENTRATIONS OF INORGANIC NITROGEN WITHIN THE C-111 CANAL AND AT THE SWEVER GAGE, AUGUST, 1985-AUGUST, 1987.

39

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Figure 18. Wet Season salinity (ppt) data, August 1985.

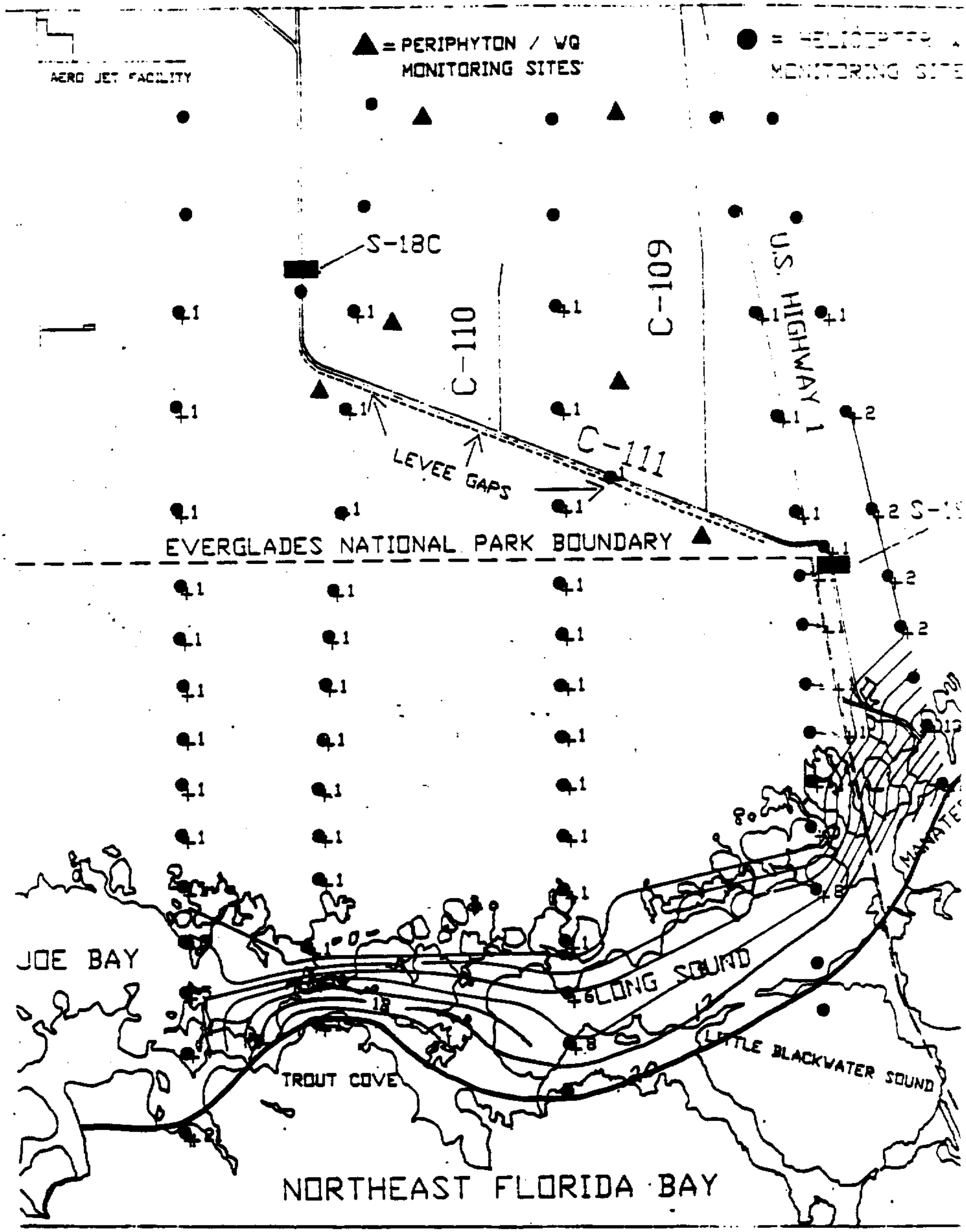




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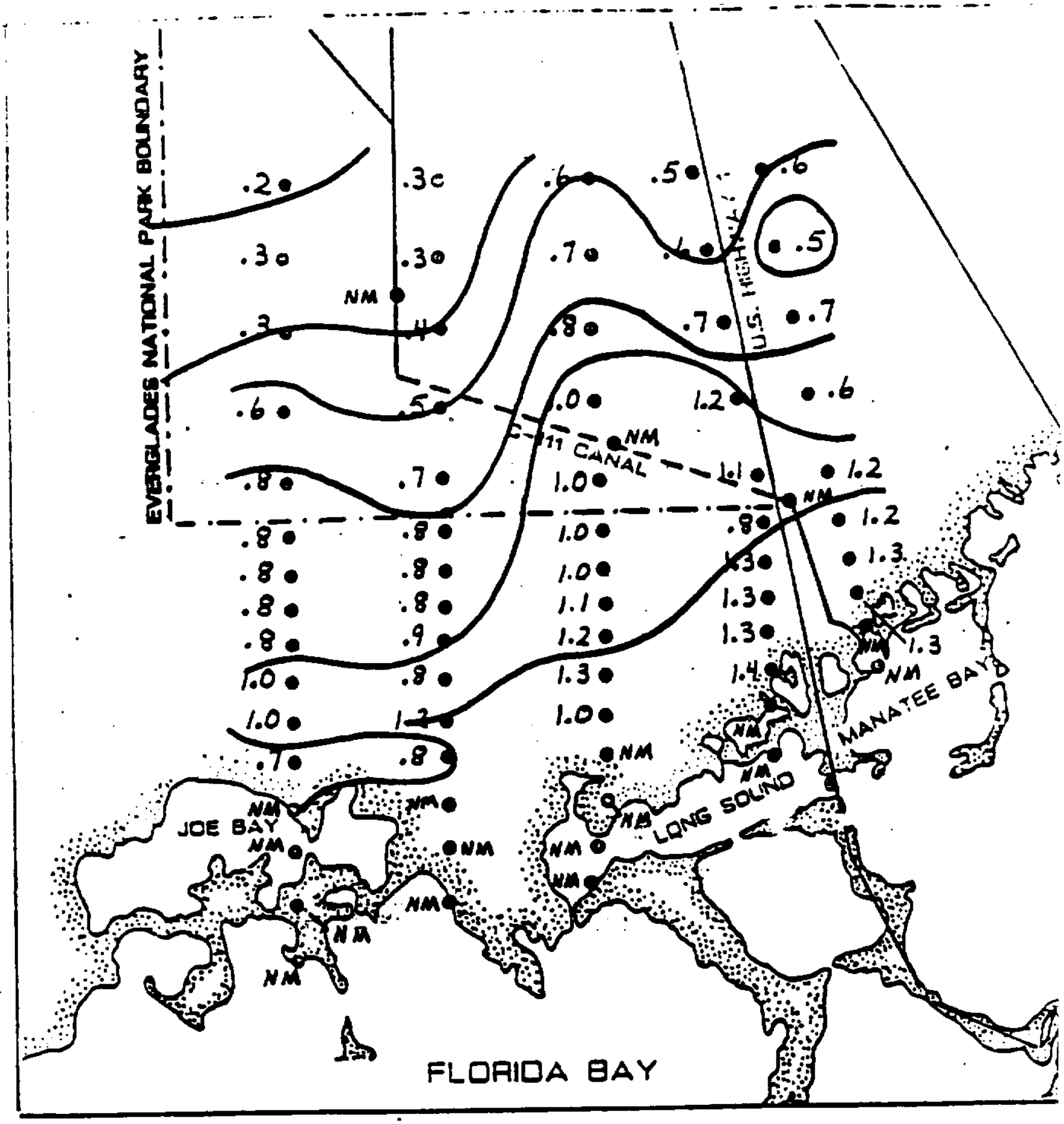
FIGURE ~~19~~ 20

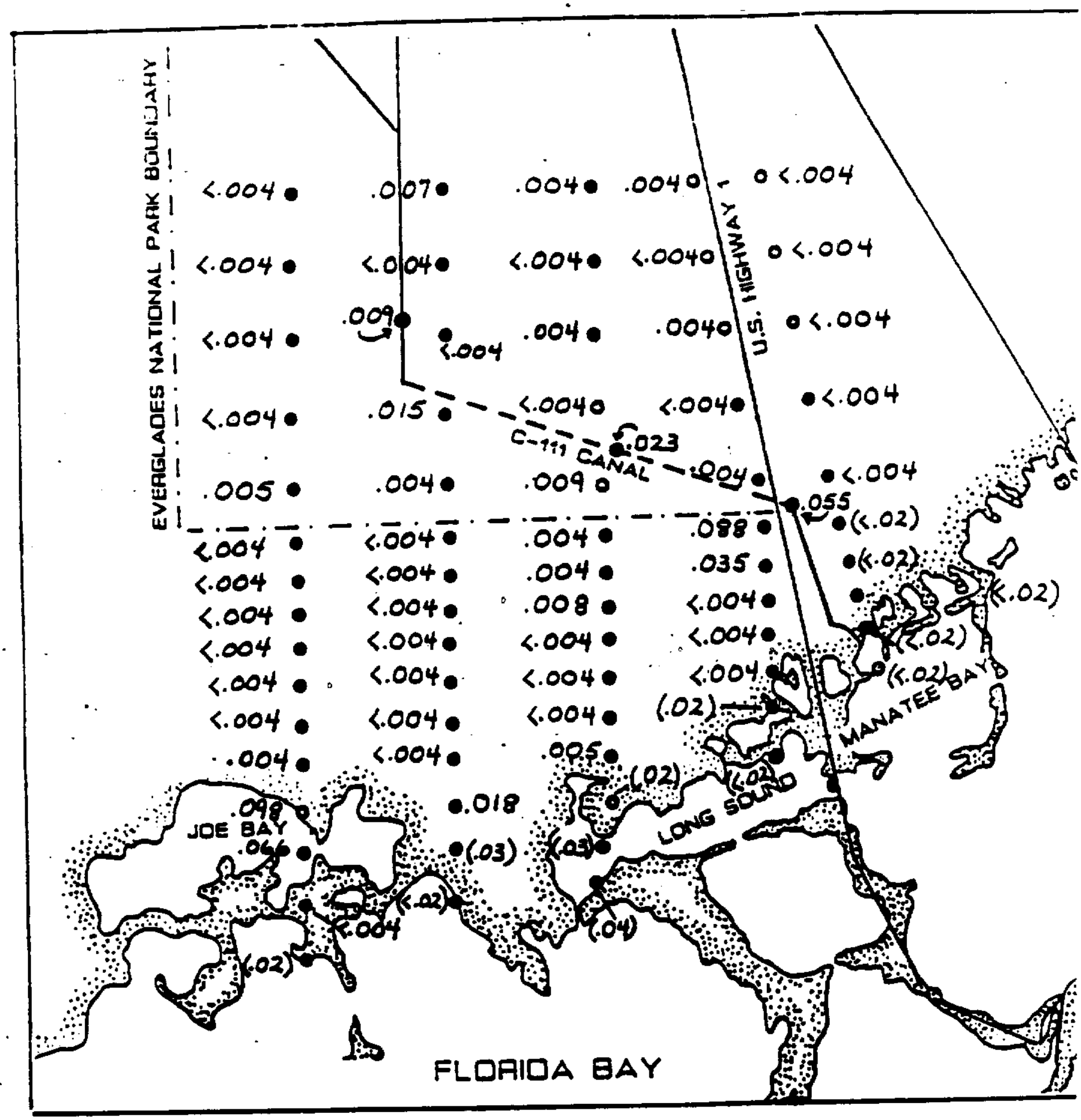



MARL DEPTH (m)
OCTOBER 23, 1985



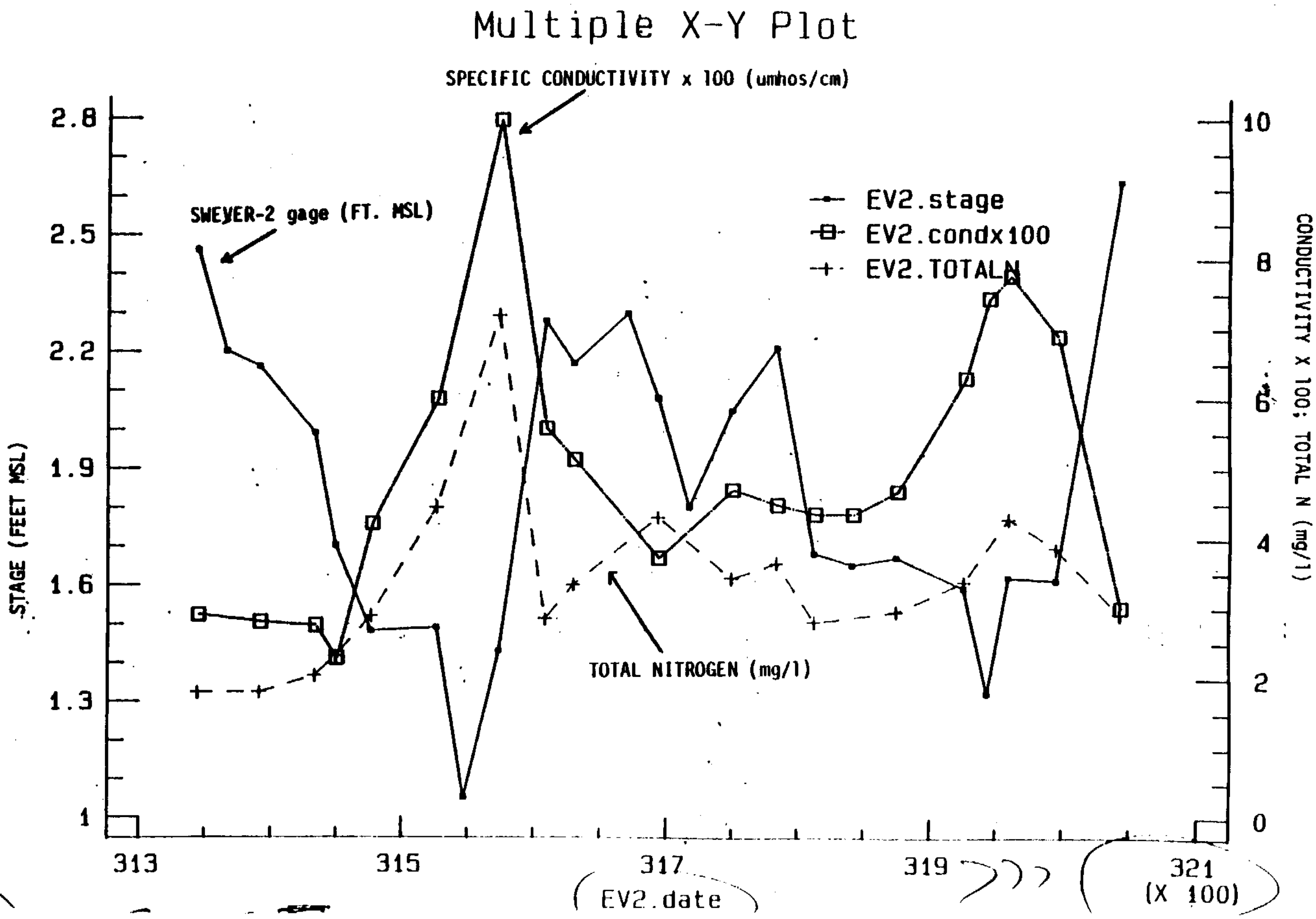
NM = NOT MEASURED

FIGURE 22




**NITRATE + NITRITE (mg/l)**
**OCTOBER 23, 1985**

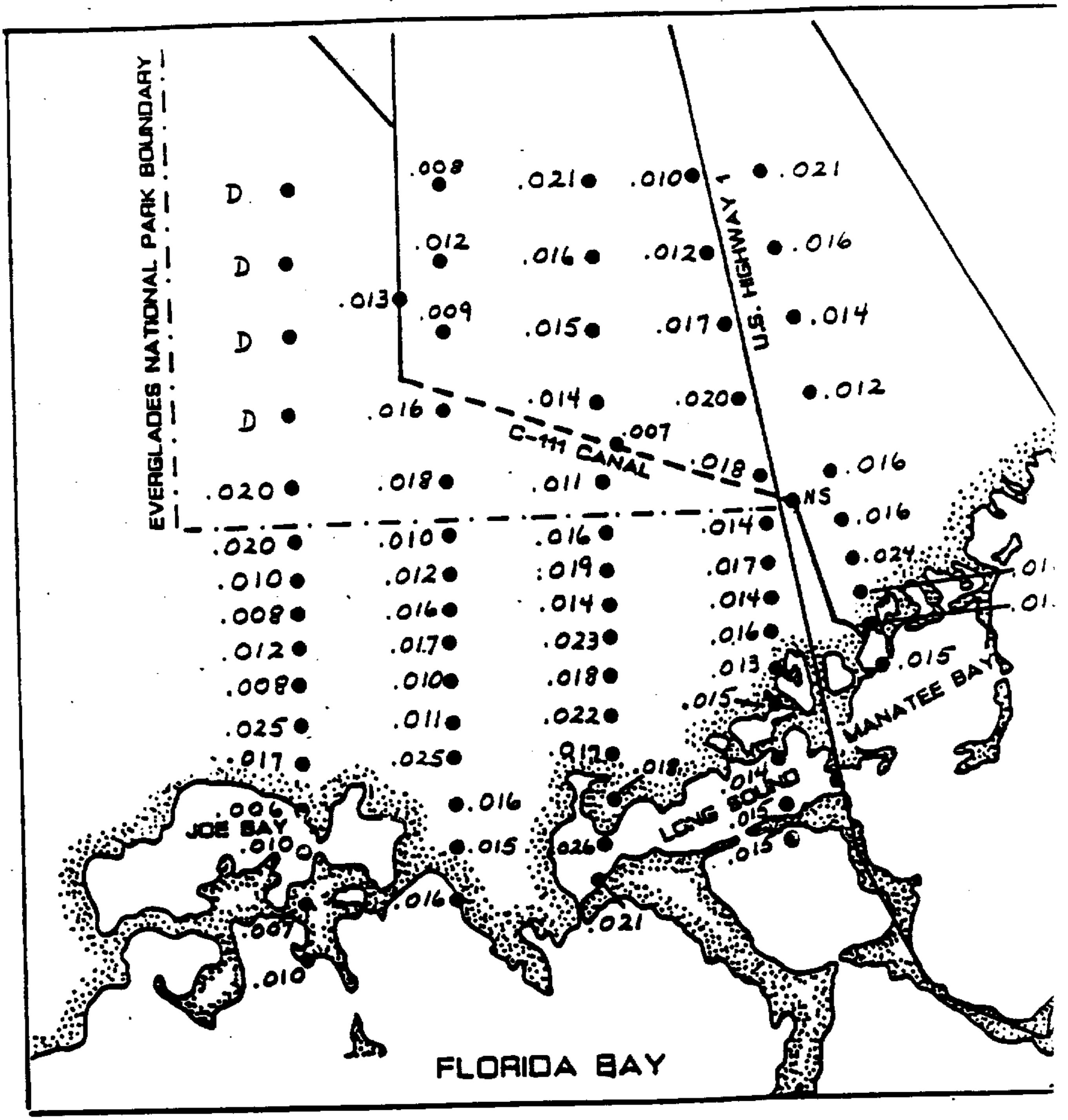
VALUES IN ( ) RPERESENT $NO_3$ VALUES CALCULATED FROM SALTWATER SAMPLES USING A HACH CHEMICAL KIT AND SPECTROPHOTOMETER READINGS. ALL OTHER $NO_3$ VALUES WERE DETERMINED USING TECHNICON AUTOANALYSER PROCEDURES. LIMITS OF DETECTION FOR SAMPLES RUN ON TECHNICON = .004 mg/l HACH KIT = .02 mg/l.



Multiple X-Y Plot
SPECIFIC CONDUCTIVITY x 100 (umhos/cm)
SWEYER-2 gage (FT. MSL)
TOTAL NITROGEN (mg/l)
EV2.stage
EV2.condx100
EV2.TOTALN
STAGE (FEET MSL)
CONDUCTIVITY X 100; TOTAL N (mg/l)
2.8
2.5
2.2
1.9
1.6
1.3
1
10
8
6
4
2
0
313
315
317
319
321
(X 100)
EV2.date

Li
365

FIGURE 25




# TOTAL PHOSPHOROUS (mg/l)
## JUNE 10-11, 1986

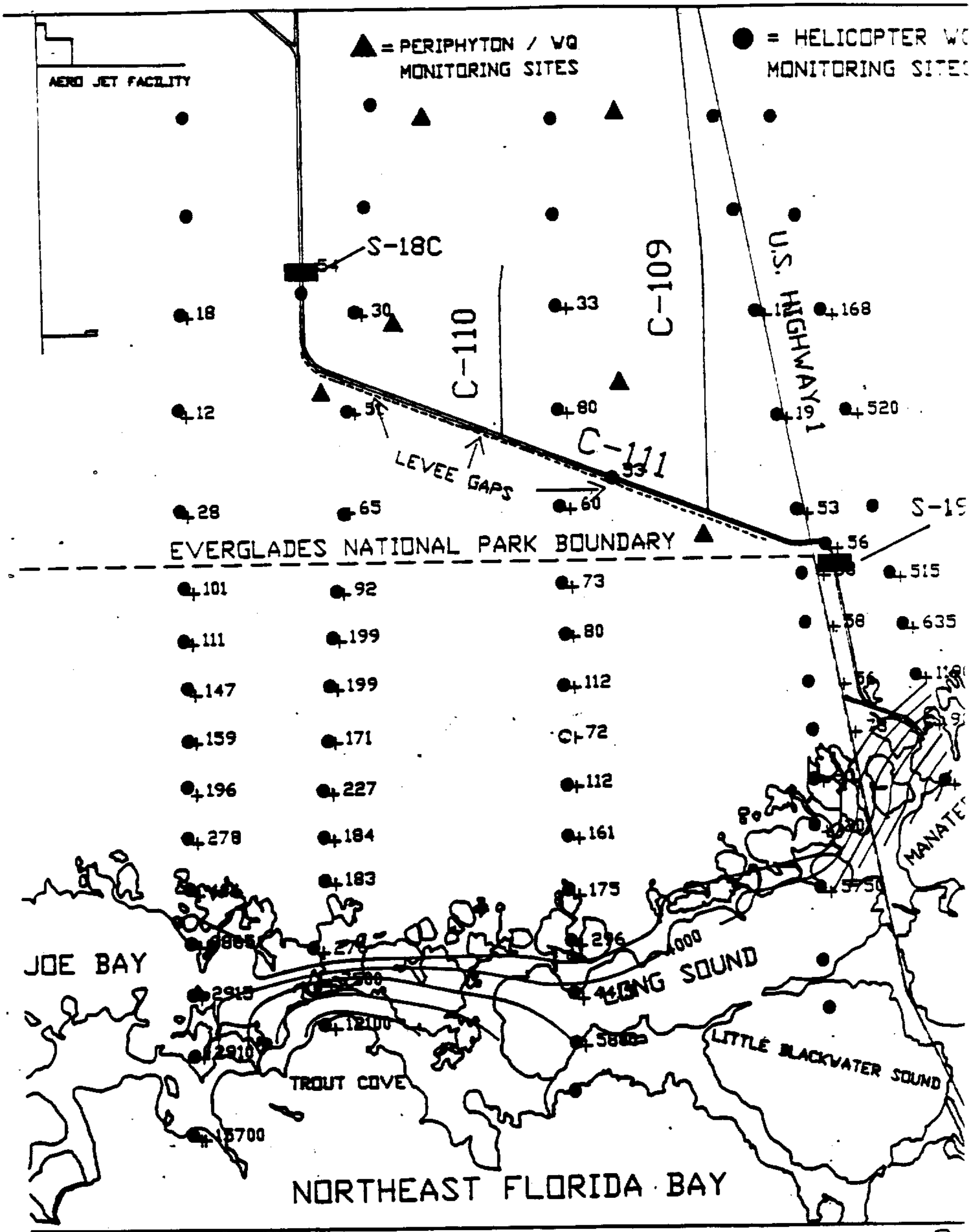
**LIMITS OF DETECTION**

**TPO4 .004mg/l**

**D = DRY MARSH**
**NS = NOT SAMPLED**

Figure 26 Chloride Concentrations (mg/L), August, 1985

(Wet Season)



western transects suggests that relatively little water moves across the marsh as sheet flow in a south or southwest direction.

A similar trend was also noted in measurements of marl soil chloride content (mg Cl/kg soil) made along transects located south of the ENP boundary (Figure 27). Results showed marl soil chloride content to vary significantly from east to west with levels increasing sharply along western transects T3, and T4 south of the ENP boundary. These data suggest western C-111 marsh soils have been previously exposed to brackish-water conditions, possibly the result of past hurricane events or the effects of periodic saltwater intrusion during the dry season.

Average concentrations of inorganic forms of nitrogen and phosphorus within the scrub mangrove marsh located 0.1 - 3.0 km north of Joe Bay, Manatee Bay and Long Sound were also low and were comparable to other areas of the C-111 marsh (Table 11). Average annual total phosphorus concentrations at these ranged between 0.011 and 0.014 mg/l, while average annual inorganic nitrogen values ranged between 0.07 and 0.18 mg/l (Table 11). Again, the low availability of nutrients within the water column during the wet season, combined with the low growth rates of the endemic scrub mangrove vegetation suggests nutrient limiting conditions for both N and P within the scrub mangrove marsh.

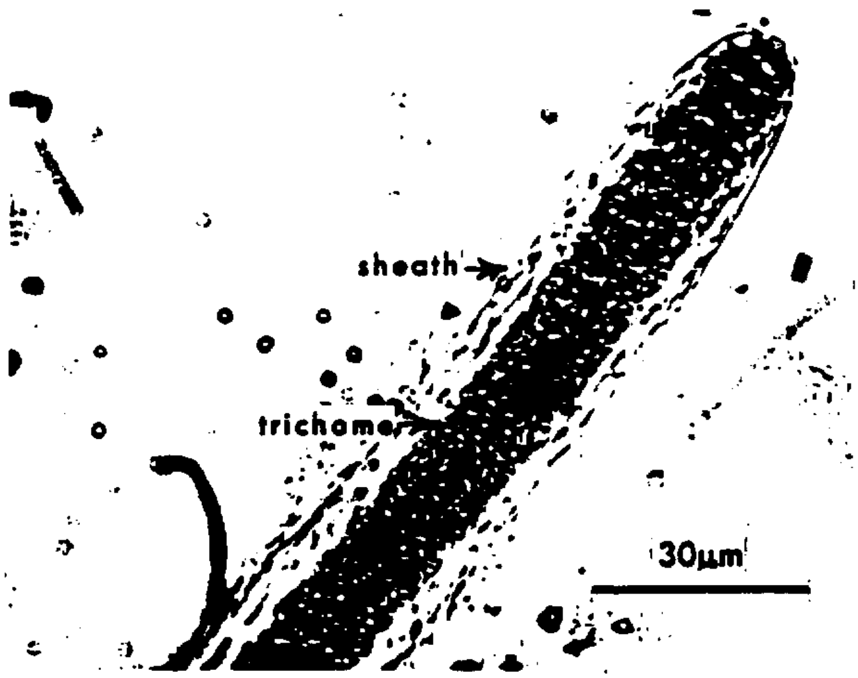
## FRESHWATER PLANT COMMUNITIES

### PERIPHYTON SPECIES COMPOSITION:

Freshwater areas of the marsh including both sawgrass wetlands and the scrub mangrove marsh were dominated by calcareous (calcium carbonate-precipitating) blue-green algae, with varying populations of diatoms, filamentous green algae and desmids, all of fresh water origin. Periphyton communities within this region of the Everglades typically form vast carpets of amber-colored algae 5 to 10 centimeters in thickness growing directly on marl sediments and frequently coat submerged plant vegetation with felt-like cylinders of encrusted algae (Van Meter, 1965, 1973; Wilson, 1974; Gleason and Spackman, 1974; Browder, 1981). Volumetrically, this periphyton community is dominated by two species of filamentous blue-green algae; Scytonema hofmannii Agardh. and Schizothrix calcicola (Agardh) Gomont. Scytonema hofmannii is the largest of the two species and is easily identified under the microscope by its hyaline sheath, false branching characteristics, and the presence of heterocysts (Figure 28a). Scytonema is one of the more common genera of algae which ,in the presence of the nitrogenase enzyme, are able to convert atmospheric nitrogen into ammonia for cell growth within the heterocyst (Steward,1969; Watanabe 1967, Fogg et al. 1973). Unpublished laboratory studies have demonstrated nitrogen fixation within similar algal mat community (ie. Scytonema hoffmanni/Schizothrix calcicola) within Water Conservation Area 3A (Goldstein, 1979).

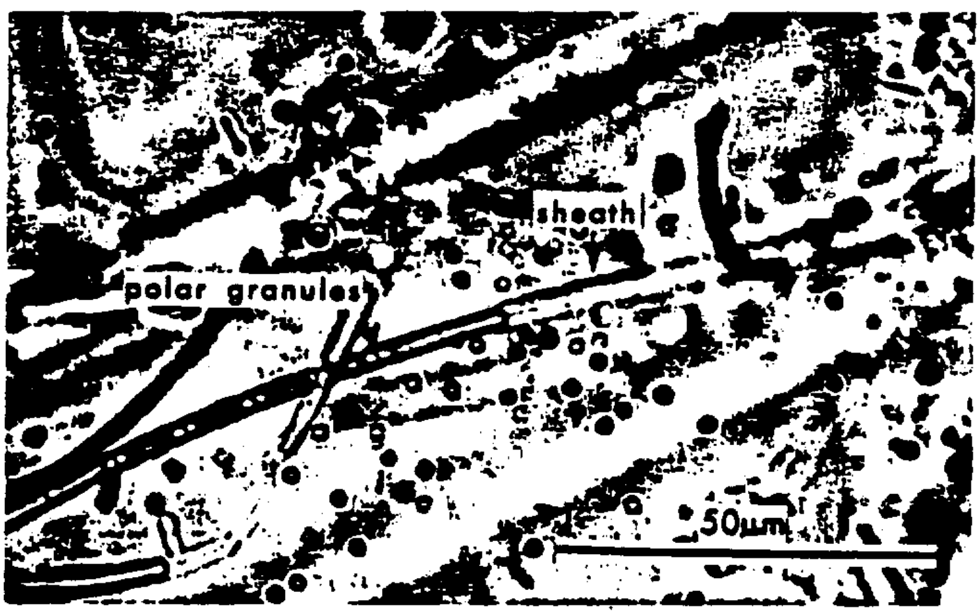
Schizothrix calcicola is a much smaller thread-like filamentous alga which lack heterocysts and consist of a trichome enclosed within a thin mucilaginous sheath (Figure 28b). Microscopic examination of the sheath of both species show them to readily precipitate calcium carbonate crystals and have been shown to be responsible for the formation of marl (calcium carbonate) soils within the southern Everglades (Gleason, 1972; Gleason and Spackman, 1974; Wilson, 1974).

Algal communities collected from seven freshwater marsh sites closely resemble those previously recorded by Wilson (1974) in her study of C-111 algal communities, as well as the calcareous periphyton communities identified by Van-Meter (1965,




28 Tip of Scytonema hofmanni filament.

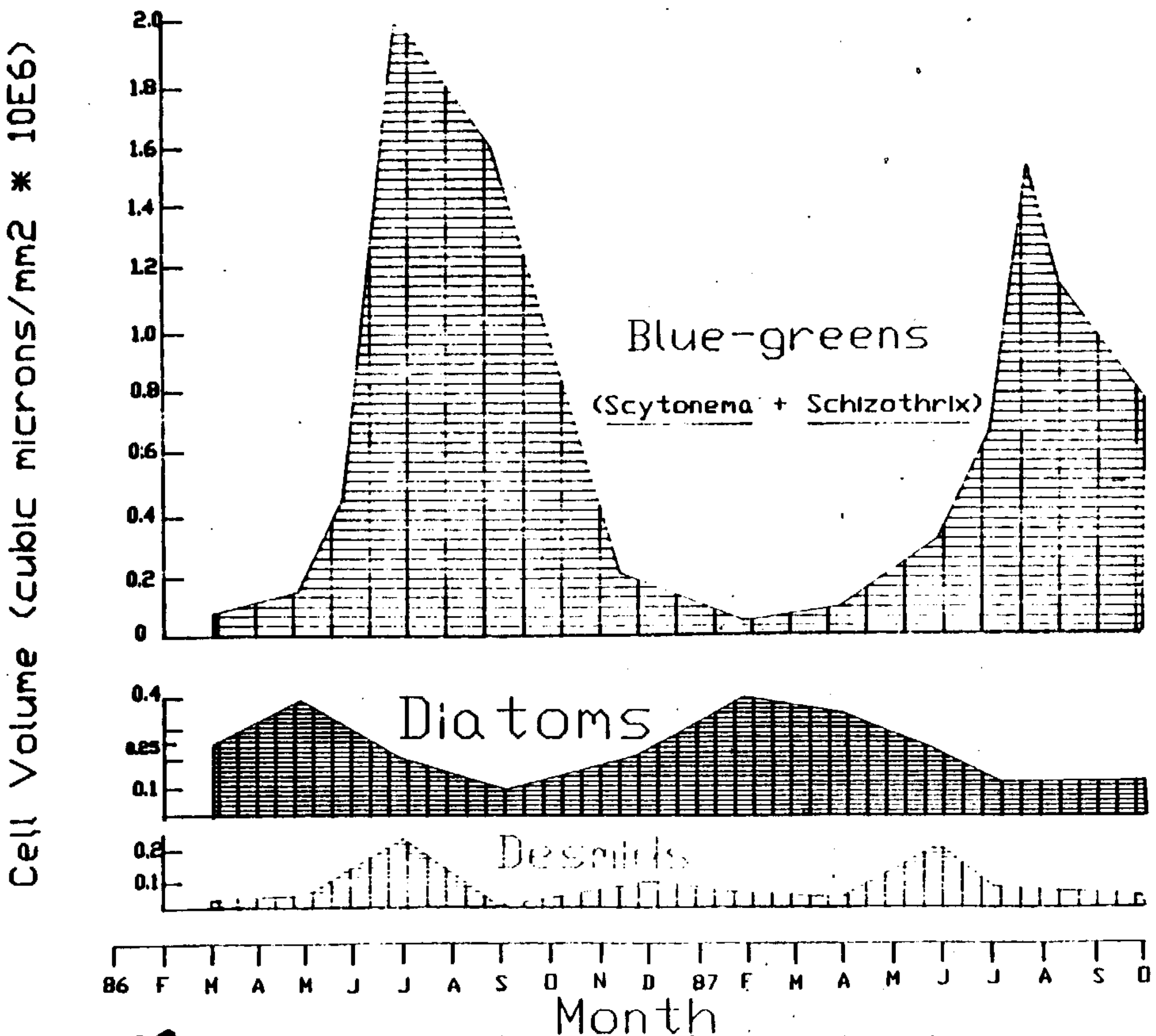
FIGURE ~~27~~ A




Filament of Schizothrix calcicola showing vacant sheath extending beyond trichome; cells in trichome display polar granules.

SOURCE: GLEASON, 1972

FIGURE 28 ~~27~~ B


Blue-greens
(Scytonema + Schizothrix)
Diatoms
Desmids
Cell Volume (cubic microns/mm2 * 10E6)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.4
0.25
0.1
0.2
0.1
86 F M A M J J A S O N D 87 F M A M J J A S O
Month

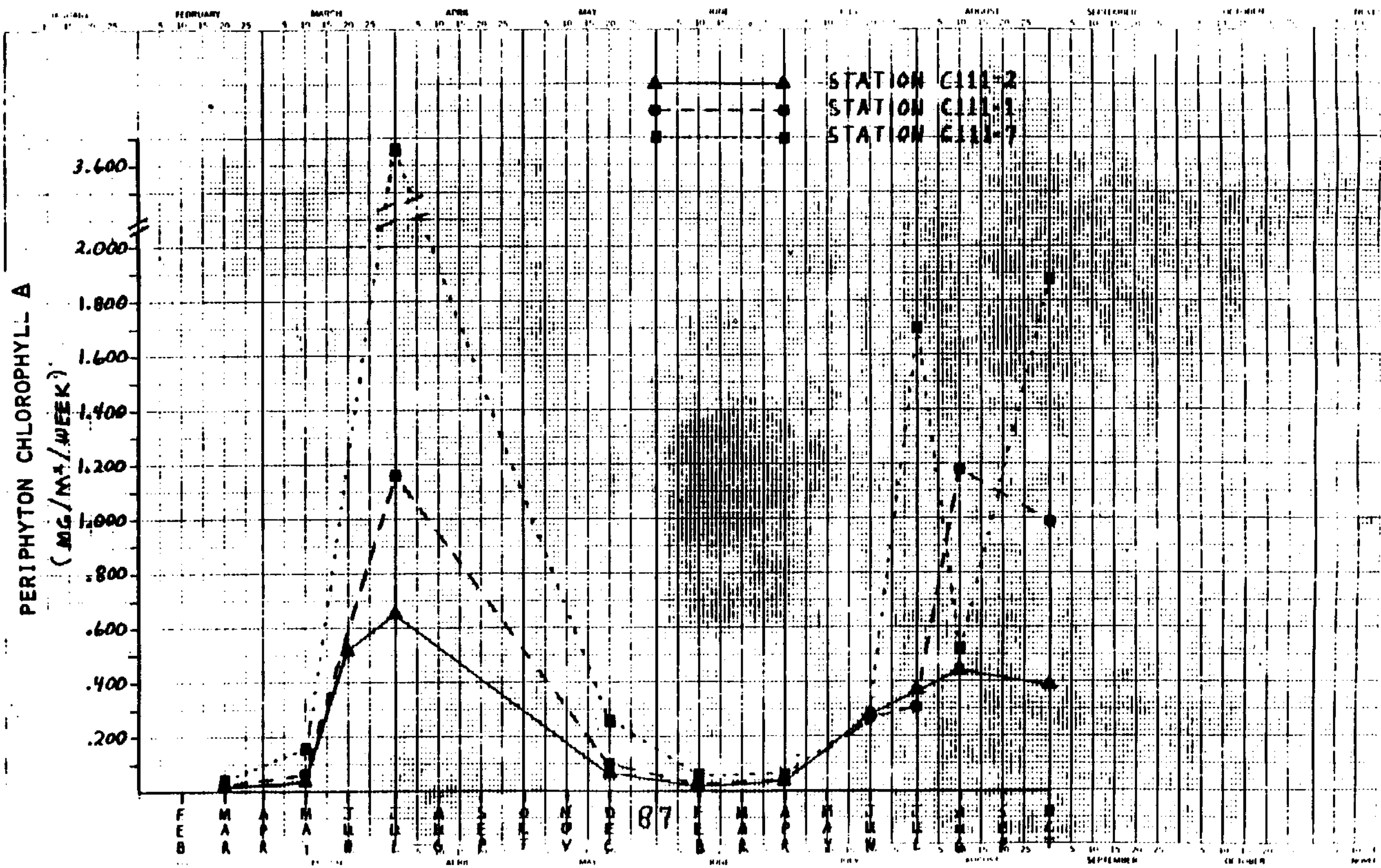



FIGURE 30. PERIPHYTON GROWTH RATES AT THREE FRESHWATER MARSH SITES IN THE C-111 BASIN.

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Table 13. Summary of diurnal dissolved oxygen monitoring statistics at SWEVER-2 and C111-7.

| Date | Average Temperature (C) | Average D.O. (mg/l) | minimum D.O. (mg/l) | maximum D.O. (mg/l) | maximum % saturation |
|---|---|---|---|---|---|
| SWEVER-2 | | | | | |
| 1/21-22/86 | 19.8 | 10.4 | 8.6 | 12 | 138 |
| 3/5-6/86 | 22.1 | 7.5 | 6.2 | 11.2 | 134 |
| 4/23-24/86 | 22.8 | 6.2 | 3.6 | 9.9 | 128 |
| 6/02-03/86 | 28.2 | 4.7 | 4.0 | 6 | 83 |
| 7/14-15/86 | 28.5 | 4.5 | 3.2 | 8.8 | 98 |
| 9/02-03/86 | 29.5 | 5.1 | 3.8 | 9 | 110 |
| 10/28-29/86 | 29.0 | 9.6 | 6.0 | 13 | 169 |
| 12/02-03/86 | 24.1 | 8.8 | 5.6 | 12.3 | 150 |
| 1/06-07/87 | 18.9 | 9.3 | 8.1 | 10.6 | 116 |
| 2/04-05/87 | 23.7 | 7.9 | 5.6 | 9.8 | 122 |
| 4/06-07/87 | 20.5 | 7.9 | 5.9 | 9.6 | 117 |
| 5/27-28/87 | 28.6 | 7.9 | 3.4 | 12.3 | 160 |
| 7/01-02/87 | 32.1 | 6.1 | 3.0 | 10 | 139 |
| 8/05-06/87 | 32.2 | 6.8 | 2.8 | 10.2 | 139 |
| 9/23-24/87 | 31.0 | 8.1 | 4.9 | 10.8 | 145 |
| C111-7 | | | | | |
| 2/17-18/86 | 17.8 | 9.9 | 6.0 | 11.5 | 132 |
| 3/06-07/86 | 18.6 | 5.1 | 3.3 | 8.7 | 102 |
| 4/23-24/86 | 21.2 | 4.1 | 2.0 | 7.2 | 87 |
| 7/15-16/86 | 30.8 | 7.6 | 2.9 | 10.9 | 143 |
| 9/10-11/86 | 29.9 | 5.0 | 2.8 | 8.4 | 128 |
| 10/28-29/86 | 25.6 | 2.6 | 0.7 | 6.1 | 74 |
| 11/07-08/86 | 27.0 | 8.8 | 6.2 | 10.5 | 139 |
| 12/03-04/86 | 19.1 | 10.3 | 8.4 | 11.8 | 142 |

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Table ~~X~~. C-111 Marsh Community Metabolism Results (g $O_2/m^2$/day)

| Site | Net Daytime Production | Night Respiration | 24 Hour Metabolism + Diffusion (1,2) | P/R Ratio (3) |
|---|---|---|---|---|
| **SWEVER-2** | | | | |
| 01/21-22/86 | 0.804 | -0.816 | -0.012 | 0.99 |
| 03/5-6/86 | 0.209 | -0.227 | -0.018 | 0.92 |
| 04/23-24/86 | 0.404 | -0.62 | -0.216 | 0.65 |
| 06/02-03/86 | 0.065 | -0.039 | 0.026 | 1.67 |
| 07/14-15/86 | 1.21 | -1.295 | -0.085 | 0.93 |
| 09/02-03/86 | 0.96 | -1.02 | -0.06 | 0.94 |
| 10/28-29/86 | 1.472 | -1.63 | -0.158 | 0.90 |
| 11/05-06/86 | 1.365 | -1.495 | -0.13 | 0.91 |
| 12/2-3/86 | 1.317 | -0.993 | 0.324 | 1.33 |
| 01/06-07/87 | 0.744 | -0.634 | 0.11 | 1.17 |
| 02/04-05/87 | 0.68 | -0.682 | -0.002 | 1.00 |
| 03/2-3/87 | 0.295 | -0.311 | -0.016 | 0.95 |
| 04/6-7/87 | 0.24 | -0.578 | -0.338 | 0.42 |
| 05/27-28/87 | 1.341 | -1.471 | -0.13 | 0.91 |
| 07/01-02/87 | 0.926 | -0.85 | 0.076 | 1.09 |
| 08/05-06/87 | 0.954 | -0.894 | 0.06 | 1.07 |
| 09/23-24/87 | 0.935 | -1.53 | -0.595 | 0.61 |
| AVG. | 0.773 | -0.838 | -0.065 | 0.914 |
| STD | 0.447 | 0.447 | 0.145 | 0.262 |
| Min | 0.065 | -1.630 | -0.338 | 0.415 |
| MAX | 1.472 | -0.039 | 0.324 | 1.667 |
| **C111-7** | | | | |
| 02/17-18/86 | 0.256 | -0.331 | -0.075 | 0.77 |
| 03/05-06/86 | 0.609 | -0.621 | -0.012 | 0.98 |
| 04/23-24/86 | 0.686 | -0.62 | 0.066 | 1.11 |
| 07/15-16/86 | 3.163 | -2.981 | 0.182 | 1.06 |
| 09/10-11.86 | 0.96 | -1.01 | -0.05 | 0.95 |
| 10/28-29/86 | 0.808 | -1.867 | -1.059 | 0.43 |
| 11/07-08/86 | 1.295 | -1.351 | -0.056 | 0.96 |
| 12/03-04/86 | 1.119 | -1.287 | -0.168 | 0.87 |
| AVG. | 1.112 | -1.259 | -0.147 | 0.892 |
| STD | 0.831 | 0.797 | 0.358 | 0.199 |
| Min | 0.256 | -2.981 | -1.059 | 0.433 |
| MAX | 3.163 | -0.331 | 0.182 | 1.106 |

(1) Uncorrected for diffusion. A value of zero was used for diffusion in the U.S.G.S. computer program to give an overall total oxygen balance, including diffusion.

(2) Net daytime production - night respiration

(3) P/R = Production/night respiration

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ble ~~9~~ 15. COMMUNITY METABOLISM CHARACTERISTICS OF VARIOUS AQUATIC SYSTEMS

| Location | 24 hour Community Metabolism (grams O2/M2/day) | Reference |
|---|---|---|
| SWEVER-2 | .32 to -.034 | This study |
| C111-7 | 0.18 to -1.06 | This study |
| Nutrient enriched site WCA-2A | .26 to -0.02 | [redacted] |
| Pristine aquatic slough WCA-2A | .36 to -0.61 | Belanger & Platko,1986 |
| Armstrong Slough Florida | .07 to -0.6 | [redacted] |
| WCA-3A | .65 to -.27 | [redacted] |
| Silver Springs Florida | 30 to 5.2 | [redacted] |
| Shallow Algal Mat | | |
| High Nutrients | 2.80 to -2.44 | Richards[redacted] |
| - Low nutrients | | |
| Algal Mat Community Texas | 4.54 | [redacted] |
| Beach Pool Texas | 5 | Odu[redacted] |



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Table ~~15~~ 16 MEAN % COVER AND (FREQUENCY) OF THE VEGETATION IN THE SEVEN SUB-AREAS AT C-111

| SPECIES | 1 | 2 | 3 | 4 | 5 | 6 | - |
|---|---|---|---|---|---|---|---|
| Cladium jamaicensis | 16.7(100) | 11.6(100) | 14.3(100) | 8.7(100) | 9.4(1000 | 14.6(100) | 20.5(100) |
| Eleocharis cellulosa | 19.5(96) | 15.6(78) | 0.5(30) | <0.1(10) | 0.5(20) | 19.8(98) | 18.8(86) |
| Rhynchospora tracyi | <0.1(2) | - | <0.1(4) | 0.1(12) | 0.9(64) | <0.1(2) | <0.1(4) |
| Utricularia sp. | - | - | 0.2(14) | - | 0.5(24) | 0.6(70) | 11.3(100) |
| Rhyncospora microcarpa | <0.1(6) | - | <0.1(4) | 0.4(86) | 3.4(90) | <0.1(8) | - |
| Crinum americanum | - | - | <0.1(6) | - | <0.1(2) | 0.2(22) | <0.1(2) |
| Rhizophora mangle | 0.1(12) | 0.1(18) | - | - | - | - | - |
| Aster tenuifolius | - | - | <0.1(10) | 0.2(44) | 0.2(40) | <0.1(2) | - |
| Panicum tenerum | - | - | <0.1(6) | 0.1(12) | 0.4(84) | - | - |
| Eragrostis elliottii | - | - | 0.1(8) | <0.1(6) | 0.4(70) | - | - |
| Andropogon virginicus | - | - | 0.1(8) | <0.1(4) | 0.3(54) | - | - |
| Bulbostylis ciliatifolia | - | - | <0.1(2) | <0.1(2) | <0.1(10) | - | - |
| Pluchea sp. | - | - | - | <0.1(4) | <0.1(2) | <0.1(8) | - |
| Schoenus nigricans | 0.1(4) | - | - | 11.8(72) | 26.9(67) | - | - |
| Aristida simpliciflora | - | - | - | 0.1(26) | 0.3(56) | - | - |
| Muhlenbergia capillaris | - | - | <0.1(10) | - | <0.1(4) | - | - |
| Ludwigia alata | - | - | <0.1(8) | - | 0.1(16) | - | - |
| Solidago sempervirens | - | - | - | <0.1(6) | <0.1(6) | - | - |
| Eupatorium leptophyllum | - | - | <0.1(4) | <0.1(2) | - | - | - |
| Sagittaria lancifolia | - | - | <0.1(2) | - | <0.1(4) | - | - |
| Cuscuta sp. | - | - | - | - | 0.2(44) | - | - |
| Rhynchospora divergens | - | - | - | - | 0.2(38) | - | - |
| Proserpinaca palustris | - | - | <0.1(2) | - | <0.1(6) | - | - |
| Oxypolis filiformis | - | - | - | - | <0.1(6) | 0.1(2) | - |
| Rhynchospora inundata | 0.4(40) | - | - | - | - | - | - |
| Utricularia cornuta | - | - | - | - | <0.1(4) | - | - |
| Utricularia subulata | - | - | <0.1(4) | - | - | - | - |
| Chara sp. | - | <0.1(2) | - | - | - | - | - |
| Juncus sp. | 0.1(12) | - | - | - | - | - | - |
| Bacopa caroliniana | - | - | <0.1(6) | - | - | - | - |
| Peltandra sp. | - | - | - | - | <0.1(8) | - | - |
| Conocarpus erectus | - | - | - | 0.1(14) | - | - | - |
| Taxodium distichum | - | - | <0.1(4) | - | - | - | - |
| Chrysobalanus icaco | - | - | <0.1(2) | - | - | - | - |
| Persea borbonia | - | - | <0.1(2) | - | - | - | - |
| Myrica cerifera | - | - | - | <0.1(2) | - | - | - |
| Mikania scandens | - | - | - | - | <0.1(6) | - | - |
| Agalinis maritima | - | - | - | - | <0.1(16) | - | - |
| Cynoctonum mitreola | - | - | - | - | <0.1(2) | - | - |
| Centella asiatica | - | - | - | - | <0.1(2) | - | - |

Table 17

COMPOSITION, DENSITY AND MEAN LENGTH OF FISH
DRY SEASON 1986 (N=60)
SUB-AREAS 1,2,6 & 7

| FISH SPECIES | TOTAL NO. OF FISH | % OF TOTAL | DENSITY (FISH/M2) | MEAN TOTAL LENGTH (MM) | STD |
|---|---|---|---|---|---|
| Jordanella floridae | 369 | 47.5 | 6.1 | 25.7 | 4.67 |
| Gambusia affinis | 145 | 18.7 | 2.4 | 24.1 | 4.97 |
| Lucania goodei | 43 | 5.5 | 0.7 | 25.7 | 5.03 |
| Fundulus chyrsotus | 55 | 7.1 | 0.9 | 31.6 | 5.69 |
| Fundulus confluentus | 25 | 3.2 | 0.4 | 40.7 | 5.74 |
| Fundulus seminolis | 6 | 0.8 | 0.1 | 44.3 | 4.03 |
| Lepomis macrochirus | 9 | 1.1 | 0.2 | 31.9 | 9.00 |
| Heterandria formosa | 25 | 3.2 | 0.4 | 18.9 | 2.00 |
| Fundulus grandis | 1 | 0.1 | <0.1 | 37.0 | – |
| Cyprinodon variegatus | 10 | 1.3 | 0.2 | 29.8 | 4.31 |
| Poecilia latipinna | 71 | 9.1 | 1.2 | 26.7 | 5.43 |
| Ictalurus natalis | 10 | 1.3 | 0.2 | 64.1 | 18.80 |
| Lepomis microlophus | 4 | 0.5 | <0.1 | 36.2 | 10.96 |
| Fundulus sp. | 3 | 0.4 | <0.1 | 35.2 | 9.47 |
| TOTALS | 776 | 99.8 | 13.0 | | |

Table 19

DENSITY OF ORGANISMS AND AVERAGE WATER DEPTH
WET VS. DRY SEASON 1986
SUB-AREAS 1,2,6 & 7

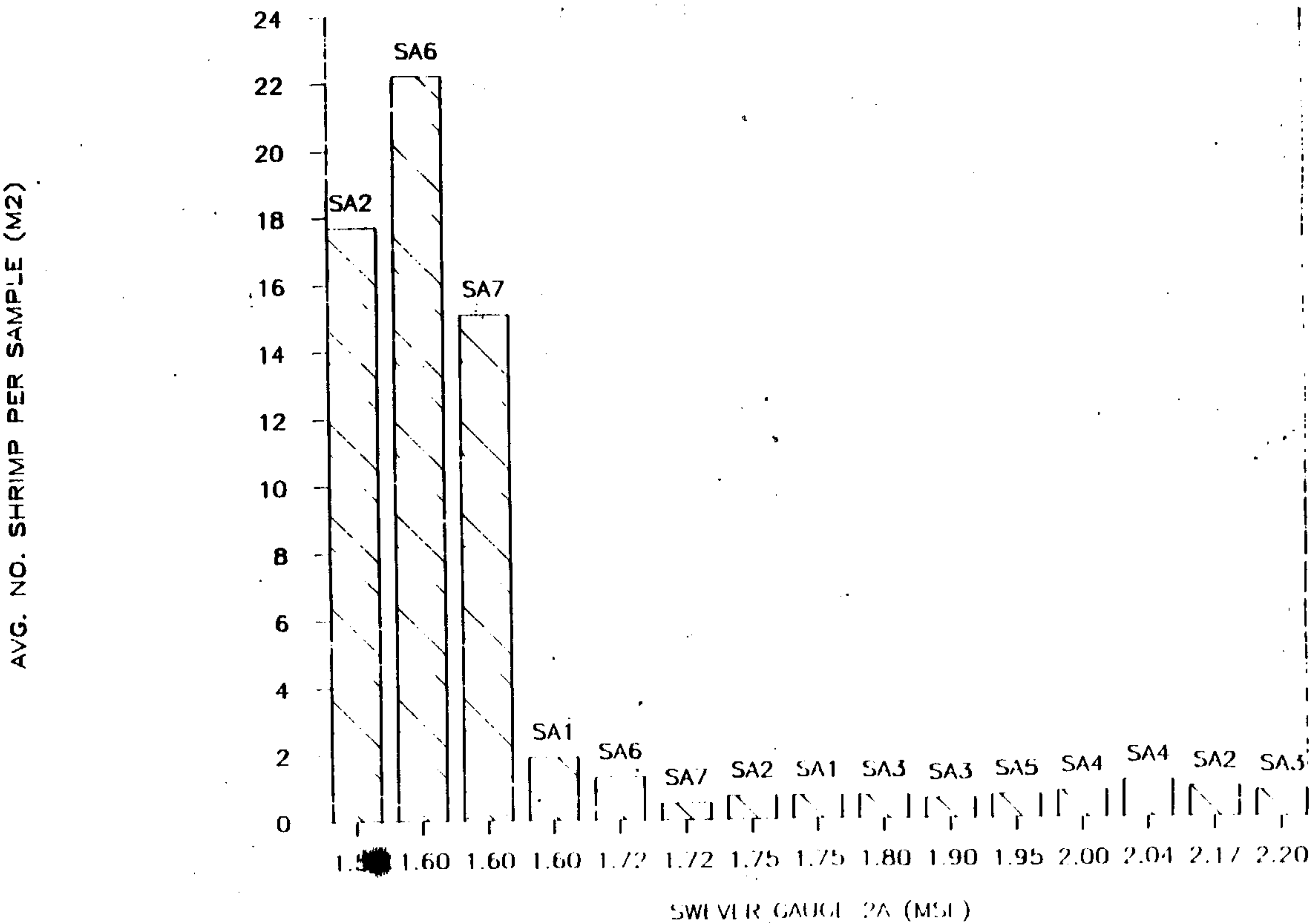
| | WET SEASON (N=45) | STD | DRY SEASON (N=60) | STD | t-test |
|---|---|---|---|---|---|
| AVERAGE DEPTH | 24.8 | 4.0 | 25.1 | 2.8 | ns |
| RANGE (CM) | 19 - 33 | | 20 - 31 | | |
| FISH /M2 | 4.0 | 5.3 | 13.1 | 11.6 | p<.001 |
| RANGE | 0 - 29 | | 1 - 50 | | |
| CRAYFISH /M2 | 2.4 | 3.0 | 2.8 | 2.7 | ns |
| RANGE | 0 - 14 | | 0 - 11 | | |
| SHRIMP /M2 | 0.8 | 1.4 | 14.2 | 22.4 | p<.001 |
| RANGE | 0 - 5 | | 0 - 92 | | |

Table 20

DENSITY OF ORGANISMS AND AVERAGE WATER DEPTH
PERIPHYTON SUBSTRATE VS. ORGANIC SUBSTRATE
SUB-AREAS 1,2,6 & 7

| | PERIPHYTON (N=120) | STD | ORGANIC (N=69) | STD | t-test |
|---|---|---|---|---|---|
| AVERAGE DEPTH | 23.9 | 3.7 | 25.7 | 3.7 | $p<.025$ |
| RANGE (CM) | 19 -32 | | 20 - 36 | | |
| NO. OF SPECIES | 2.1 | 1.5 | 3.2 | 1.6 | $p<.001$ |
| RANGE | 0 - 6 | | 0 - 7 | | |
| FISH /M2 | 3.6 | 3.7 | 12.1 | 11.5 | $p<.001$ |
| RANGE | 0 - 24 | | 0 - 50 | | |
| CRAYFISH /M2 | 2.9 | 3.1 | 4.6 | 5.0 | ns |
| RANGE | 0 - 15 | | 0 - 30 | | |
| SHRIMP /M2 | 1.7 | 6.0 | 10.6 | 20.9 | $p<.001$ |
| RANGE | 0 - 41 | | 0 - 92 | | |

C-111 SHRIMP DENSITY VS. WATER LEVELS

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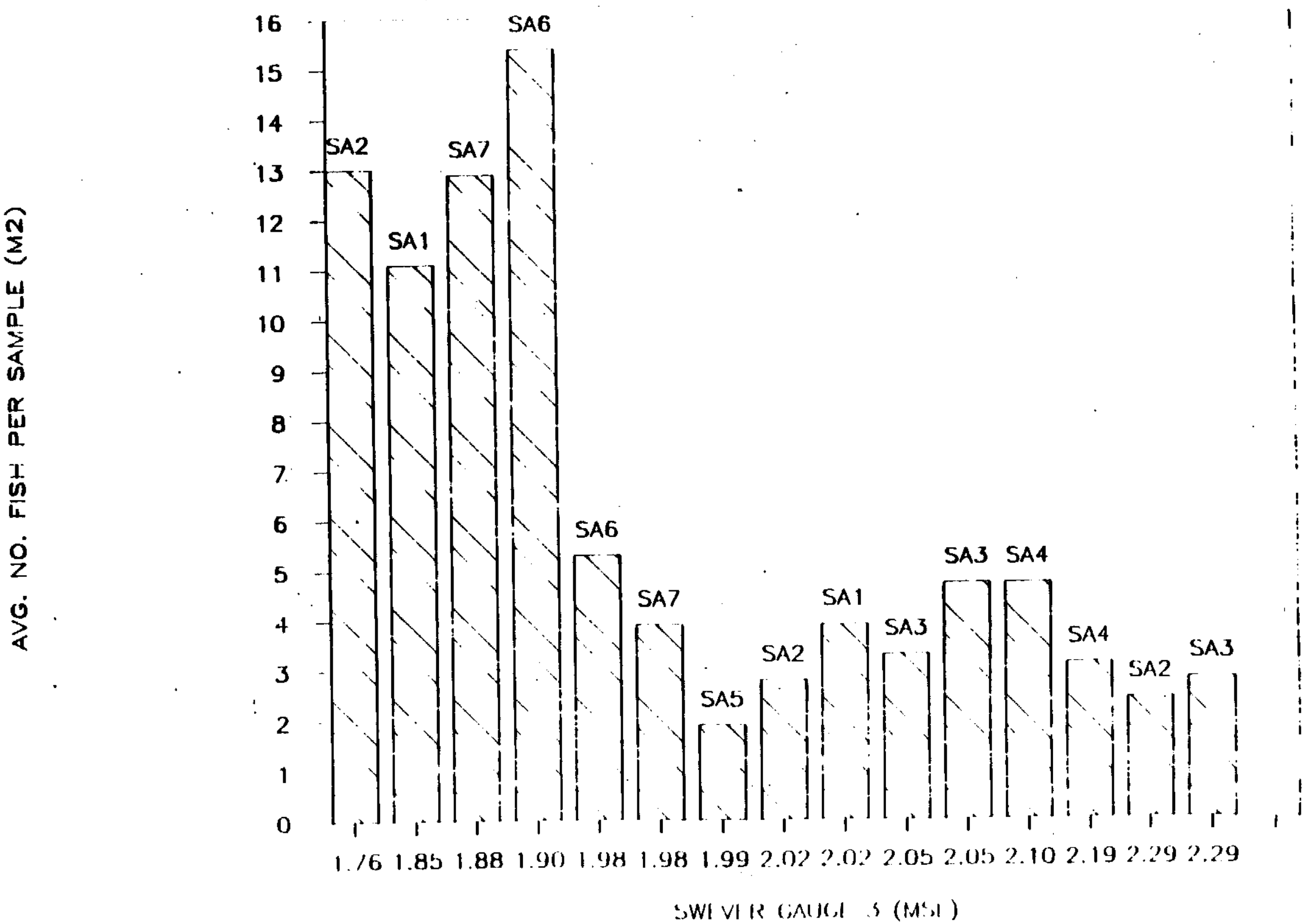
# C-111 FISH DENSITY VS. WATER LEVELS

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I. Water Quality

Twenty water quality surveys were conducted at approximately monthly intervals between December 1985 and September 1987 at 19 locations (Figure 1). Additional surveys were completed in August 1985 and 1988 when the earthen plug at S-197 was removed. Sampling stations within the Everglades National Park (Stations 1 to 3) receive significantly greater freshwater flows from the C-111 gaps than Manatee Bay/Barnes Sound area (Stations 4 to 19) does from S-197. This provided some contrast in water quality between sampling areas.

Surface water quality samples were collected at seven of the 19 stations when in situ measurements were obtained (Figure 1) and were analyzed for macro-nutrients (TKN, $NH_4$, Total $PO_4$, and ortho-$PO_4$), suspended solids, turbidity, color, chl a, as well as other parameters. A hydrolab data logger (Model 4041) was employed for in situ measurements of conductivity (latter converted to salinity), dissolved oxygen, temperature, and pH at 0.5m intervals in the water column. Field salinty measurements were also obtained with a hand-held refractometer (American Optical Corp.) and compared to hydrolab data. Salinity and temperature in north Manatee Bay was continuously monitored with USGS standard equipment.

II. Copepod Densities

To determine copepod densities, three one gallon samples were collected randomly near the seven surface water quality stations with a 800 gal/hr bulge pump (Zillioux, 1982). The pump and tubing was fastened to a 2m PVC pipe enabling each replicate sample to be taken from throughout the water column. This procedure reduced problems associated with vertical differences in copepod densities (Barlow, 1955; Reeve and Casper, 1973). Samples were sieved through a 30 micron plankton net with the remaining sample preserved in a 5% formalin solution. Preserved organisms and seston components formed aggregates and therefore alliquot sampling could not be used to enumerate specimens. Copepod nauplii and adults (copepodid and adult stages) were placed on a grided petri dish and counted with the aide of a disecting scope. Intermittent taxonomic identifications of copepod adults confirmed that Acartia tonsa was the overwhelming dominate copepod species in the samples.

III. Seagrasses

An aerial photograph of Manatee Bay was taken on 10 February 1987 to document the distribution of seagrasses. Kodak color 2443 film (9 x 9 in format) and a Wratten #12 filter were employed to produce a photograph at a 1 in = 1000 ft scale. Efforts to obtain an aerial photograph during peak seagrass abundance (May-June) were hampered due to cloud cover.

Ground truthing was accomplished by establishing 22 east to west transects spaced about 500 ft apart. Species composition and density of seagrasses were observed along each transect by a skin diver in July and August of 1987. A modification of Mueller-Dambois D. and Ellenberg (1974) plant cover methods were utilized to qualitatively document densities of seagrasses. By observation, four density levels of Halodule wrightii (shoal grass) and seven levels of Thalassia testudinum (turtle grass) were quantitatively documented. Quantitative densities of mixed grasses were not determined. A $0.1m^2$ PVC pipe filled with sand was divided into quadrants with monofiliment line. Blades and shoots were enumerated within each quadrant, averaged and corrected to $m^2$ densities:

Thalassia testudinum

| Density Level | Blades/m2 | Shoots/m2 |
|---|---|---|
| 1 Low | 162 | 79 |
| 2 Low Medium | 485 | 268 |
| 3 Medium Low | 552 | 306 |
| 4 Medium | 618 | 333 |
| 5 Medium High | 985 | 407 |
| 6 High | 1217 | 518 |
| 7 Very High | 1942 | 953 |

Halodule wrightii

| Density Level | Blades/m2 | Shoots/m2 |
|---|---|---|
| 1 Low | 992 | 426 |
| 2 Medium | 2460 | 936 |
| 3 High | 5735 | 2072 |
| 4 Very High | 8917 | 2757 |

Depth of substrate and water may influence the density of seagrasses. To measure substrate depth less than a meter, a meter stick was pentrated into the calcarious mud bottom every 20 ft along several transects until bedrock was reached. Bathymetry of Manatee Bay was determined by establishing 31 east/west transects spaced 300 ft apart to reference depths recorded with a Model 1350 King Marine Fish Finder. The depth recorder was used in conjunction with a King Marine 8001 Loran-C Receiver for concurrent location data. As a verification, locations along the transects were also approximated by calculating the distance traveled from the shoreline. Chart depths were corrected to NGVD by logging the time of depth measurements and referencing the surveyed elevation of the S-197 downstream stage recorder. The Synagraphic Mapping System (SYMAP) computer program was employed to produce a depth contour map.

IV. Statistical Methods

Simple linear regression techniques were applied to determine relationships ($P=.05$) among data. Meaningful significant correlations among copepod densities ($\log_{10}(X+1)$), water quality, estimated flow through the C-111 gaps and S-197, local rainfall, stage data SWEVER1 were plotted with 95% confidence belts for each regression. Relationships were established for each station, each group of stations in the ENP (Stations 1, 2, and 3) and Manatee Bay area (Stations 4, 9, 13, and 17) as well as for all stations combined for overall trends.

## RESULTS

### Water Quality

I. In-situ measurements

The average value of conductivity, dissolved oxygen, pH, and temperature for the water column was determined for all 19 stations on every sample date during study (data available upon request). In general, a conductivity or salinity gradient usually exist in the ENP whereas salinities are more uniform and high in the Manatee concentrations also existed at relatively low levels throughout the study period (avg. = 0.010 mg/l) with a maximum concentration occurring in May 1987 (.039 mg $TPO_4$/l). Again, the low supply of nutrients within this system suggests that nutrients may be limiting within Manatee Bay, at least for a portion of the year.

Although S-197 releases could not be directly correlated to increase in nutrient concentrations within the bay, maximum chlorophyll a concentrations (1.0 mg/m$^3$) occurred during September 1986, one month following peak discharges through S-197. Increased chlorophyll a levels experienced later during 1987 may be the result of increased $TPO_4$ and freshwater inflows (through rainfall) within the bay.

Chlorophyll a levels within the bay were low throughout the year with concentrations ranging between 0.05 (assumed limit of detection) and 1.9 mg/m$^3$. The presence of low year round concentrations of chlorophyll a coupled with the low supply of nutrients present within the bay system suggests that Manatee Bay is a naturally nutrient limited, tropical lagoon ecosystem.

IV. Seagrasses

Distribution of seagrasses were documented by an aerial photograph (Figure 3) and ground truthing. Species composition and density levels are shown in Figure 4. Three species of seagrasses were present in Manatee Bay. Thalassia testudinum (turtle grass) was the most abundant, covering approximately 93% of the bay. Halodule wrightii (shoal grass) occupied about 6% of the area and the remaining 1% by Ruppia sp. (widgeon grass).

| DENSITY LEVELS | ACRES | PERCENT |
|---|---|---|
| Medium-low Thalassia | 726 | 28 |
| Medium Thalassia | 549 | 22 |
| Medium-High Thalassia | 495 | 19 |
| High Thalassia | 266 | 10 |
| Low-medium Thalassia | 249 | 10 |
| Low Thalassia | 91 | 4 |
| Thalassia and Halodule | 83 | 3 |
| Low Halodule and Ruppia | 42 | 2 |
| Medium and High Halodule | 19 | 1 |
| Low Halodule | 19 | 1 |
| Very High Thalassia | 6 | < 1 |
| TOTALS | 2546 | 100 |

Turtle grass occurs in vast submarine fields around the Florida coast from just below the low tide mark to about 40 ft (Hanlon and Voss, 1975). The optimum salinity range for turtle grass is from 25 to 38 ppt, but it can tolerate extremes of 11 and 48 ppt temporarily (Phillips, 1960).

On the east side of Manatee Bay high densities of turtle grass may be attributed to the contribution of nutrients from mangrove leaf decomposition, reduced disturbance from wave action, and water clarity. The outer edge of this high density area of turtle grass seems to follow the 2 to 3 ft depth contour line (Figure 5). In the northwest area of the Bay, high densities of turtle grass occur where tributaries and limited nutrients enter into the system. Round beds or "clumps" of high density turtle grass

Fig. 3



3.84

were also located randomly throughout the bay. In general, the medium densities of turtle grass were located in the central deep portion of Manatee Bay, possibly due to the reduced available photosynthetically active radiation. A small band of low density turtle grass occurred along the western shoreline which is frequently exposed to wave action resulting from prevailing east and southeast winds and reduced water clarity. Substrate depth did not appear to affect turtle grass density unless substrate was less than about 2 to 5 cm in depth (Figure 6 to 10). These reduced substrate depths do coincide with the low density of turtle grass located in the south-central portion of the bay.

Halodule wrightii is another tropical species which often occurs in shallow, guiet water and frequently in company with turtle grass (Dawson, 1956). It is frequently the dominant plant from mean low tide to low low tide and sometimes to about 1.0 to 0.5 ft below this level (Thorhaug, 1976). Shoal grass tolerates a wide range of salinities from 1 to 60 ppt with the extreme values being tolerated for only short periods of time (Simmons, 1957). In general, shoal grass in Manatee Bay occurred in shallow areas protected from wave action on the northeastern and northwestern shorlines.

Ruppia sp. occurs in both marine habitats and in brackish or inland alkaline waters (Dawson, 1966). It is found in salinities up to 33 ppt, but prefers salinities below 25 ppt (Hanlon and Gilbert, 1975). Sparse Ruppia sp. was found mixed with H. wrightii in the northwest area near the mouth of C-111. Freshwater flows from S-197 are wind driven into this area periodically reducing salinities.

## V. Zooplankton

Zooplankton is an essential food source for larvae of virtually all animals that inhabit the shallow marine waters south of canal C-111. Adult and juvenile forms of some fish, including those of commercial importance, and benthic invertebrates, such as sponges and mollusk, also depend on an adequate supply of zooplankton to survive.

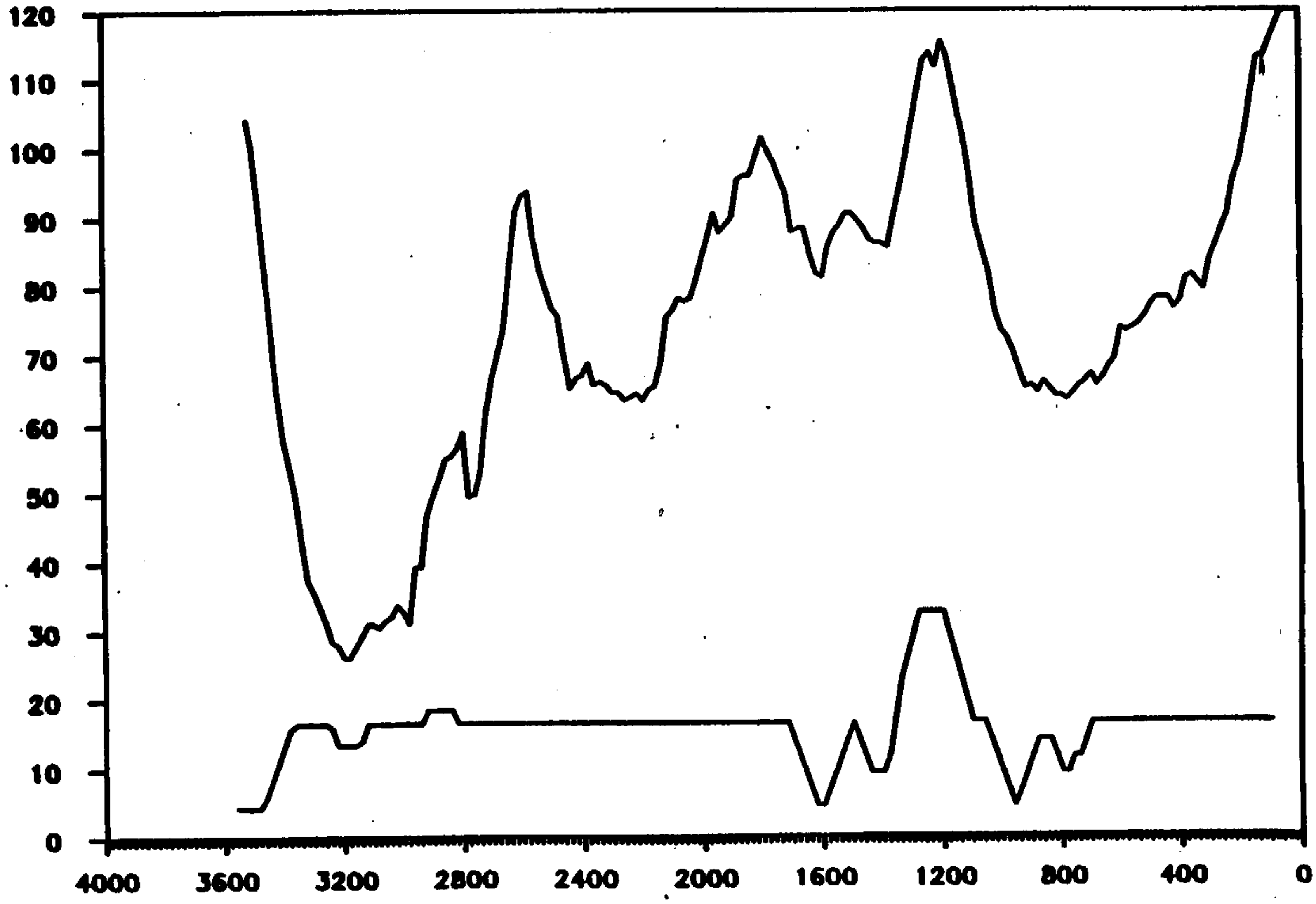
Zooplankton in the Biscayne Bay and Card Sound area are predominated by two species of copepods and their nauplii, Acartia tonsa and Paracalanus parvus. A. tonsa was found to predominate the near-shore, lower salinity areas in south Biscayne Bay (Reeve, 1975) and Card Sound (Zillioux, 1982) while P. parvus occupied the higher salinity, mid-bay portions in south Biscayne Bay. Davis (1950) considered A. tonsa to be the most common of all copepods in Florida marine waters and is abundant throughout its reported range along the east coast of the Americas extending from Micanichi Estuary at 47 5 north latitude (Bousfield, 1955) to Mar del Plata at 38 south latitude (Ramirez, 1966).

Since A. tonsa comprises the major portion of near-shore zooplankton populations, densities of this species may be considered indicative of overall zooplankton production in south Florida. Since limited information is available on copepod physiology, probably the best indicator of the degree of favorableness of the environment in its ability to reproduce. The development of A. tonsa is rapid, and breeding nonsynchronus. It can pass through a complete life cycle within two weeks. With this short generation time of A. tonsa, fluctuations in densities may reflect rapid responses to environmental change.

Zillioux (1982) determined by bioassy that A. tonsa reproduction dramatically decreased when salinities were greater than 35 ppt. It was speculated that salinities above 35 ppt within tributaries to Card Sound and other coastal areas, which may

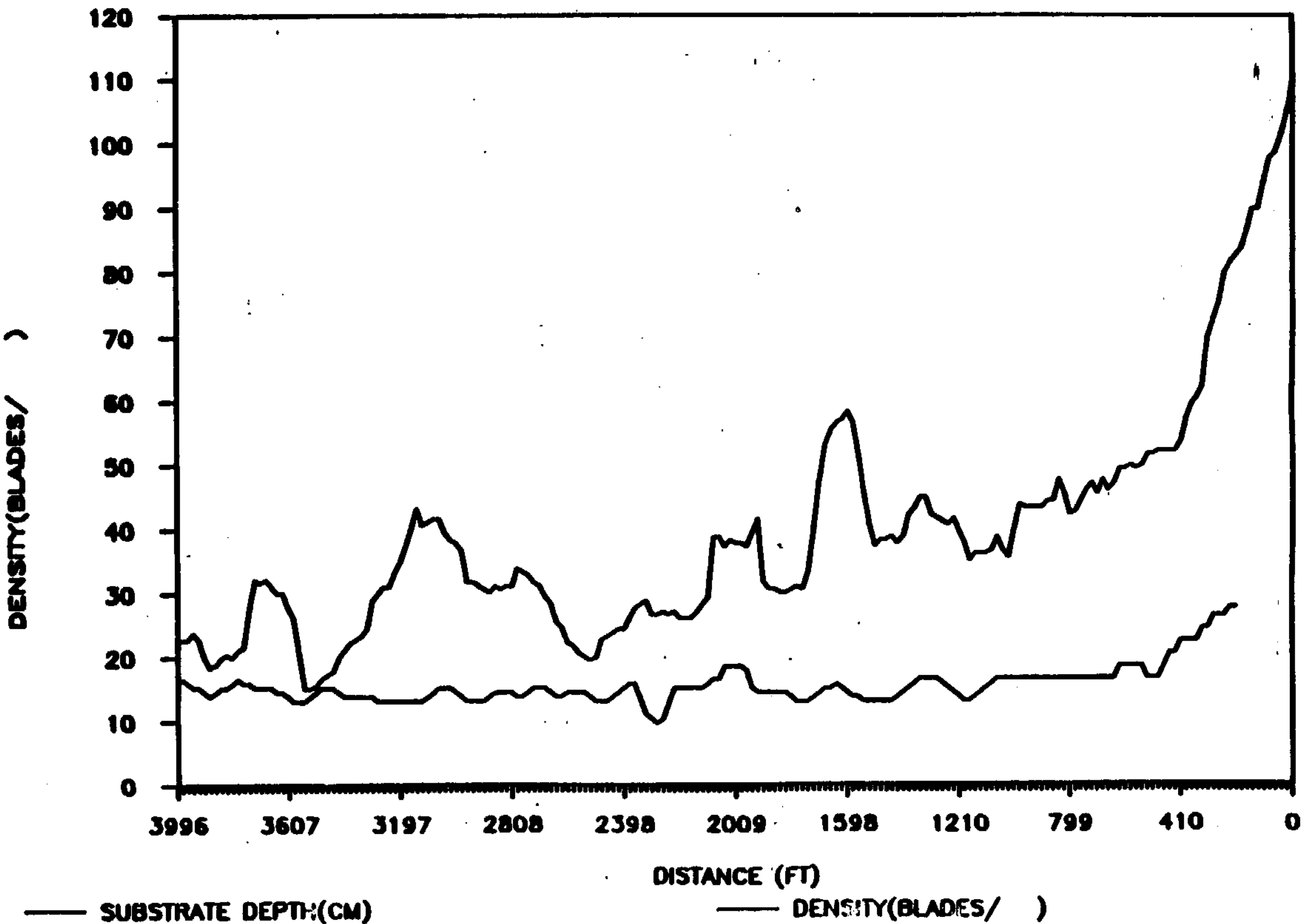
# SUBSTRATE DEPTH, THALASSIA DENSITY

TRANSECT 2



THALASSIA DENSITY

TRANSECT 4

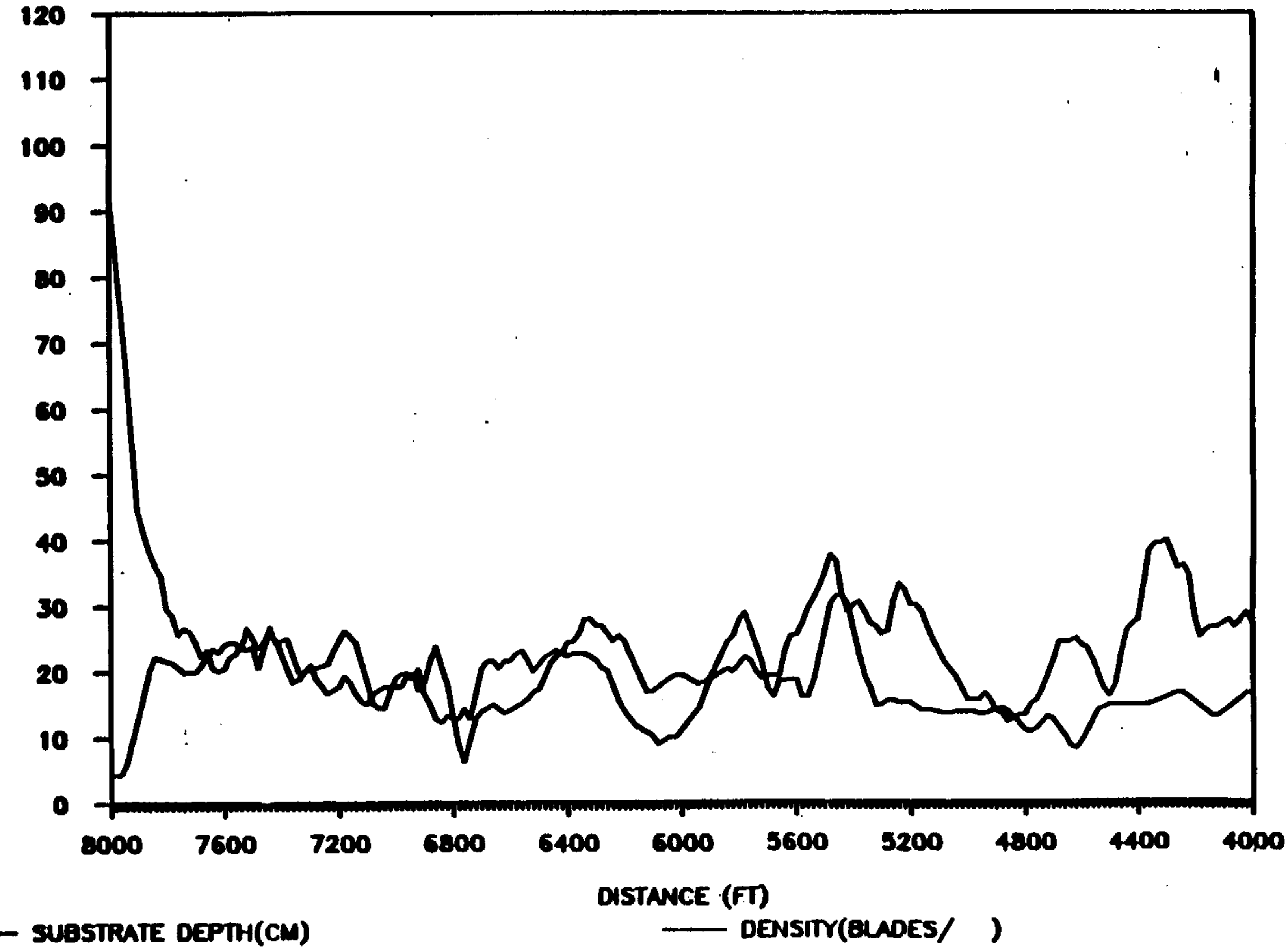



92

387

THALASSIA DENSITY

TRANSECT 8



1

TABLE ~~2~~. Statistically significant (P > .05) linear relationships among copepod densities, water quality, and other important variables

| STATIONS / VARIABLES | 1 r | 1 df | 2 r | 2 df | 3 r | 3 df | 1,2,3, Combined r | 1,2,3, Combined df | 4 r | 4 df | 9 r | 9 df | 13 r | 13 df | 17 r | 17 df | 4,9,13,17 Combined r | 4,9,13,17 Combined df | All Stations Combined r | All Stations Combined df |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copepod nauplii vs volitile solids | .58 | 15 | .59 | 15 | .67 | 15 | .55 | 45 | .49 | 13 | .50 | 15 | .51 | 15 | | | | | .47 | 115 |
| Copepod nauplii vs salinity | .42 | 18 | .53 | 18 | .73 | 18 | .46 | 56 | .63 | 16 | .50 | 18 | .41 | 18 | | | | | .47 | 136 |
| Copepod adults vs volitile solids | .73 | 15 | .49 | 15 | | | .65 | 45 | | | | | | | | | | | .53 | 115 |
| Copepod adults vs salinity | .57 | 18 | .50 | 18 | | | .64 | 56 | | | | | | | .56 | 18 | .53 | 76 | .64 | 136 |
| Copepod adults vs rain | | | | | | | | | | | | | | | -.44 | 18 | | | | |
| Salinity vs volitile solids | .73 | 15 | .75 | 15 | .60 | 15 | .74 | 45 | | | .50 | 15 | .44 | 15 | .47 | 15 | .48 | 76 | .67 | 116 |
| Salinity vs rain | -.64 | 18 | | | | | | | | | | | | | | | | | | |
| Salinity vs temperature | | | | | | | | | .79 | 17 | | | | | | | | | | |
| Salinity vs STAGE SWEVER 1 | | | | | | | | | | | | | -.57 | 18 | -.61 | 18 | | | | |
| Salinity vs GAP FLOW | -.60 | 18 | -.73 | 18 | -.60 | 18 | | | | | | | | | | | | | | |
| GAP FLOW vs rain | | | .8[illegible] | 17 | | | | | | | | | | | | | | | | |

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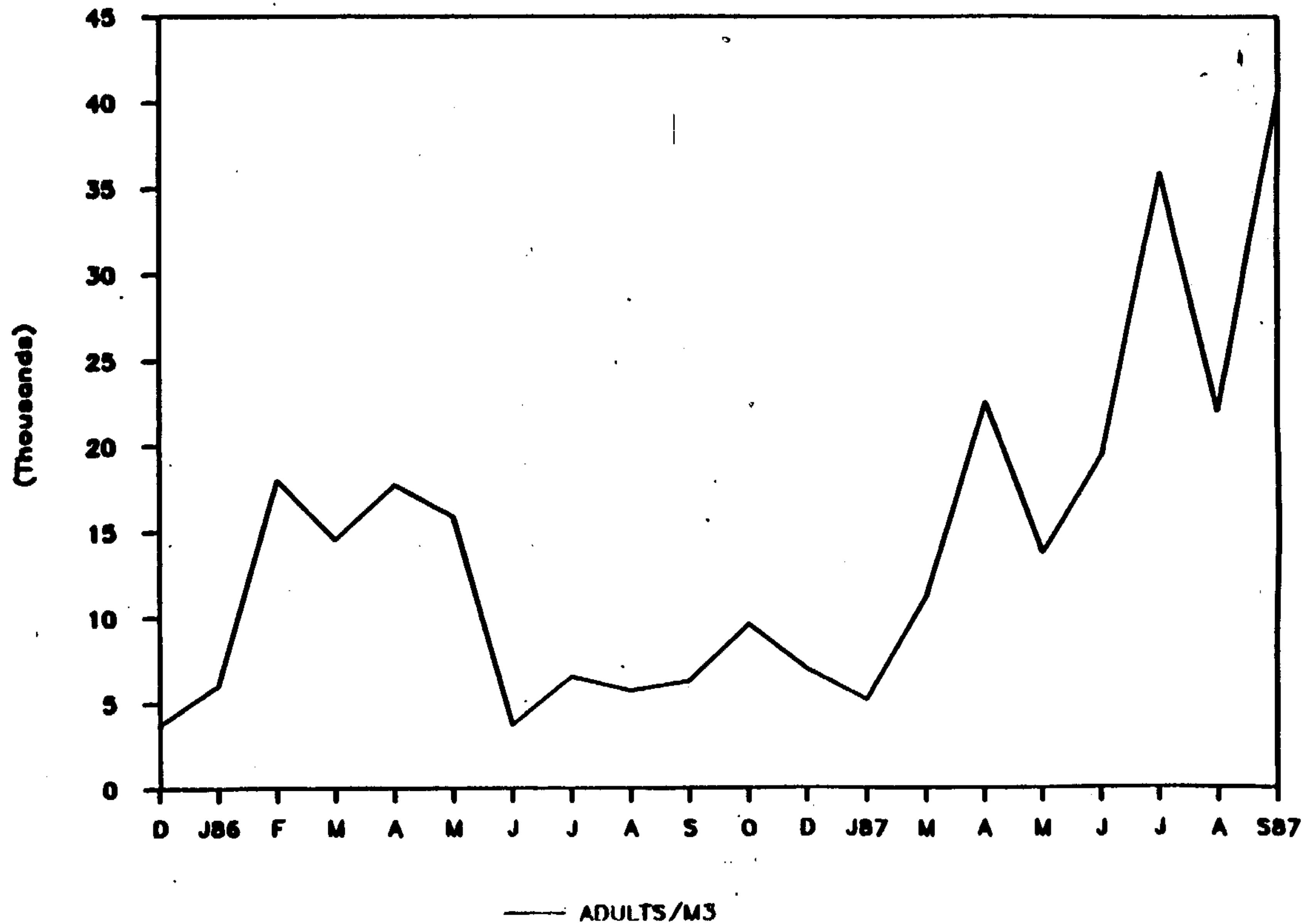
MEAN COPEPOD ADULTS IN LONG SOUND

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water flows decline there is less flushing downstream, salinities increase and wave action suspends bottom sediments and seagrass detritus. Therefore, the less freshwater flow to the system, the greater the copepod densities in these study areas (Figure 13). This relationship contrast with other studies where reduced salinities and increased flows coincide with an increase in suspended solids. The only time this relationship found for copepod production in ENP and Manatee Bay is not valid is when an atypical large flow occurs, disturbing sediments that would otherwise not be transported into the systems. During these periods, such as large releases from S-197, suspended matter increases, nutrients also increase which is followed by increases in chlorophyll a. In response copepod nauplii also increase for a short period.

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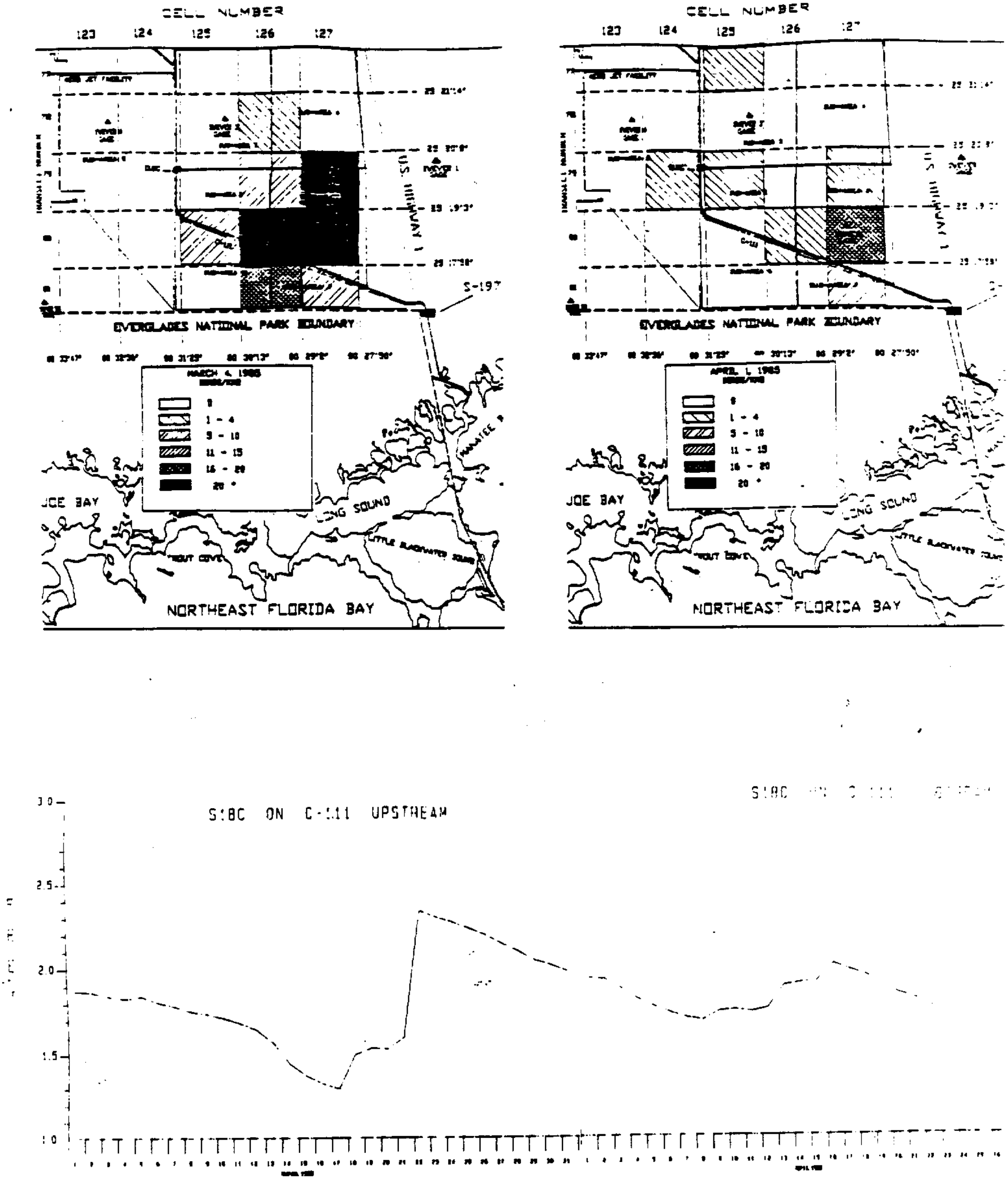
APPENDIX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123
124
125
126
127
EVERGLADES NATIONAL PARK BOUNDARY
S-197
MARCH 4, 1985
0
1 - 4
5 - 10
11 - 15
16 - 20
20 +
JOE BAY
LONG SOUND
TROUT COVE
LITTLE BLACKWATER SOUND
NORTHEAST FLORIDA BAY
APRIL 1, 1985
S18C ON C-111 UPSTREAM
3.0
2.5
2.0
1.5
1.0

FIG. 2

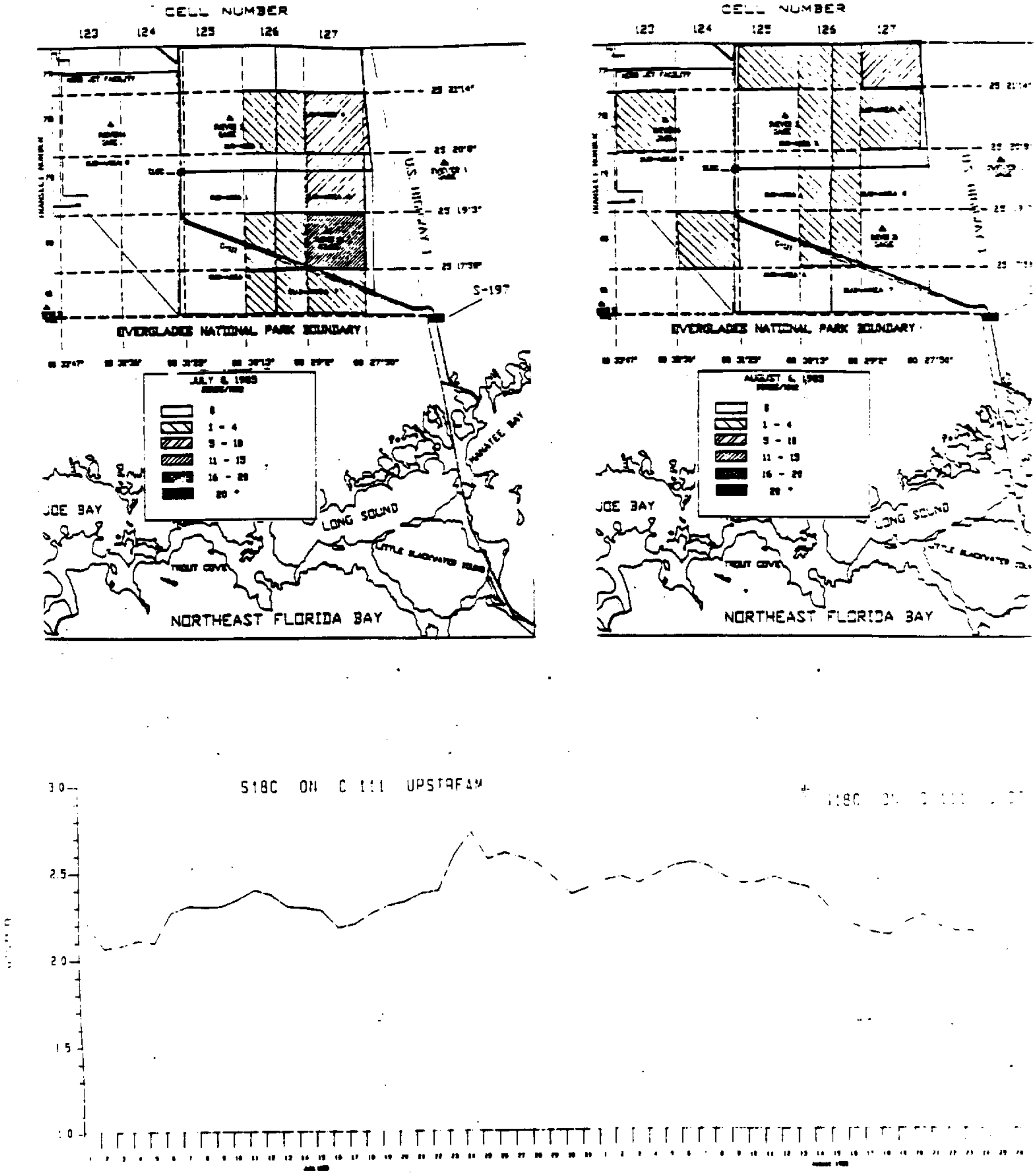
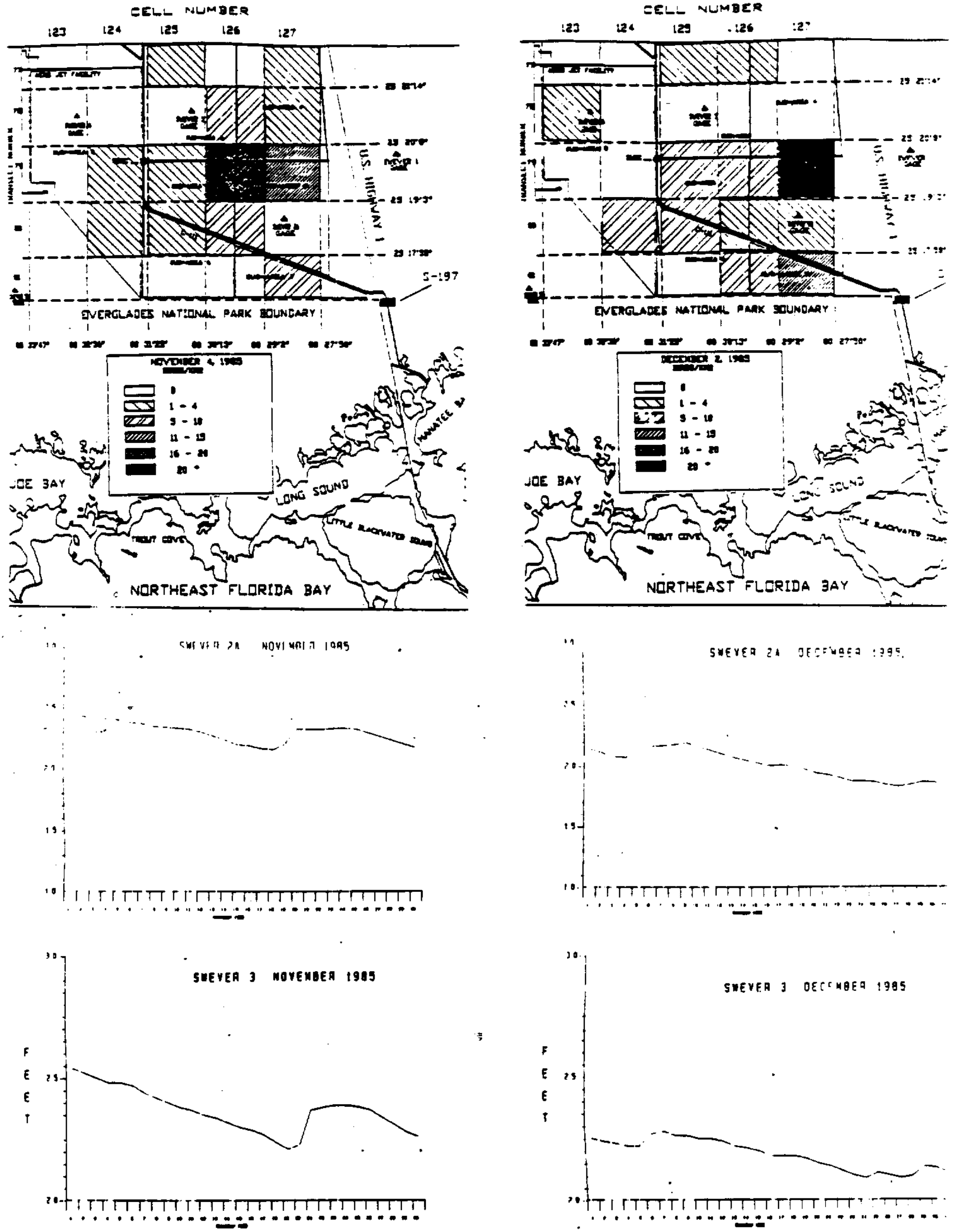

CELL NUMBER
123
124
125
126
127
EVERGLADES NATIONAL PARK BOUNDARY
S-197
U.S. HIGHWAY 1
JULY 6, 1983
AUGUST 6, 1983
0
1 - 4
5 - 10
11 - 15
16 - 20
20 +
JOE BAY
LONG SOUND
TROUT COVE
LITTLE BLACKWATER SOUND
MANATEE BAY
NORTHEAST FLORIDA BAY
S18C ON C 111 UPSTREAM
3.0
2.5
2.0
1.5
1.0

FIG. 4


CELL NUMBER
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124
125
126
127
EVERGLADES NATIONAL PARK BOUNDARY
S-197
U.S. HIGHWAY 1
NORTHEAST FLORIDA BAY
LONG SOUND
JOE BAY
TROUT COVE
LITTLE BLACKWATER SOUND
MANATEE BAY
NOVEMBER 4, 1985
DECEMBER 2, 1985
0
1 - 4
5 - 10
11 - 15
16 - 20
20 +
SWEVER 3 NOVEMBER 1985
SWEVER 3 DECEMBER 1985
FEET

FIG. 6

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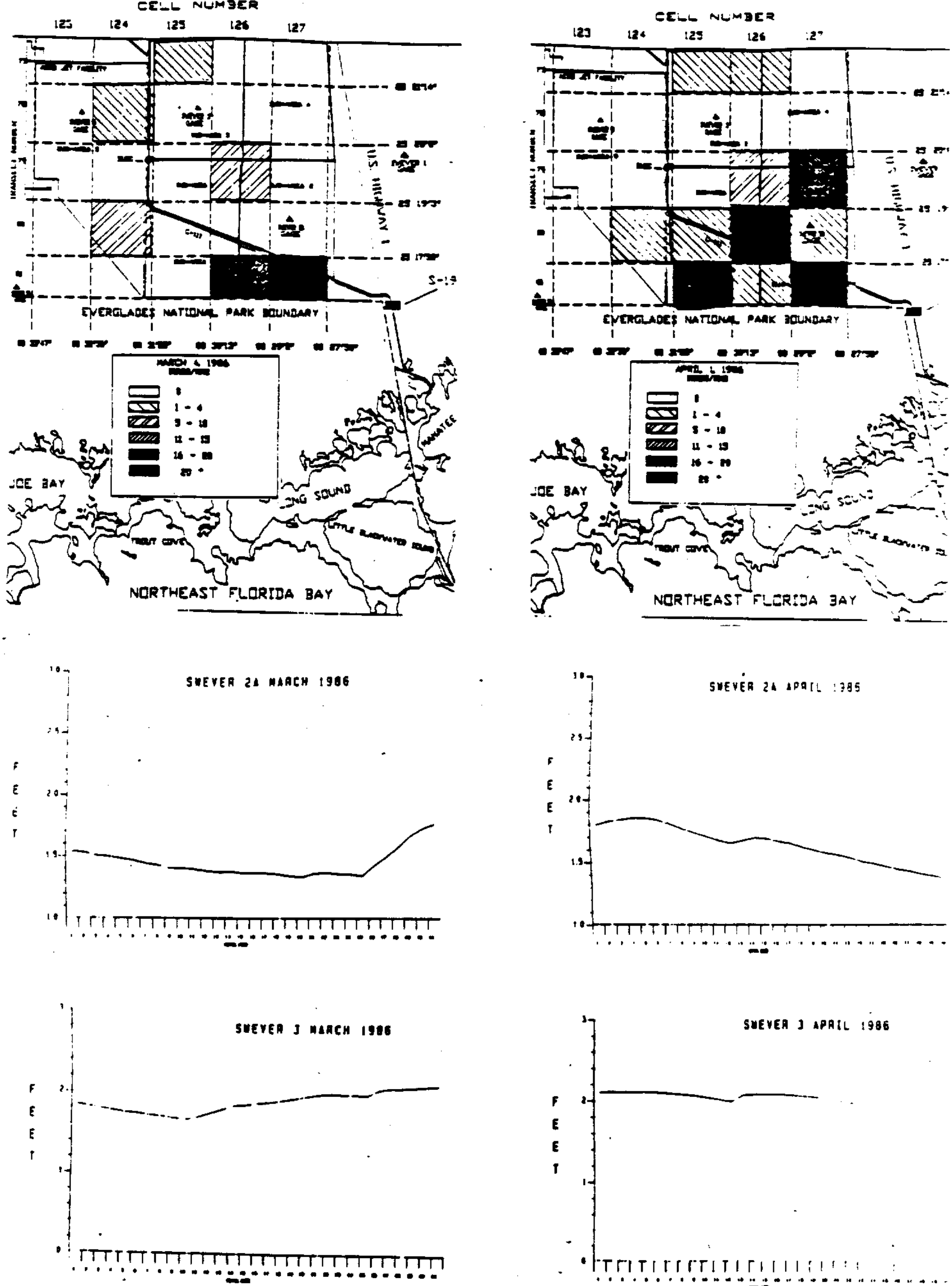
CELL NUMBER
123
124
125
126
127
U.S. HIGHWAY 1
S-19
EVERGLADES NATIONAL PARK BOUNDARY
MARCH 4, 1986
0
1 - 4
5 - 10
11 - 15
16 - 20
20 +
APRIL 1, 1986
JOE BAY
LONG SOUND
TROUT COVE
LITTLE BLACKWATER SOUND
MANATEE
NORTHEAST FLORIDA BAY
SWEVER 2A MARCH 1986
SWEVER 2A APRIL 1985
SWEVER 3 MARCH 1986
SWEVER 3 APRIL 1986
FEET

FIG. 8

Appendix 9. Freshwater flow and Mangrove habitat use by fish.



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# INFLUENCE OF CHANGES IN FRESHWATER FLOW ON THE USE OF MANGROVE PROP ROOT HABITAT BY FISH: SIX MONTH INTERIM REPORT

January 1990

Submitted by:

Janet A. Ley

University of Florida
Gainesville, Florida

To:

South Florida Water Management District
West Palm Beach, Florida

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INFLUENCE OF CHANGES IN FRESHWATER FLOW
ON THE USE OF MANGROVE PROP ROOT HABITAT BY FISH:

Six Month Interim Report

January 1990

Janet A. Ley
University of Florida
Environmental Engineering Sciences
Gainesville, Florida

## INTRODUCTION

Water management decisions can potentially impact estuarine fish production. To help quantify this impact, fish communities are being monitored in habitats that are subject to different degrees of freshwater inflow variation. Recent research has shown the importance of submerged mangrove prop roots as fish habitat in the Florida Bay system (Thayer et al 1987). By monitoring the concentrated fish community occupying red mangrove prop root habitat across a salinity gradient, corresponding differences in fish populations will be identified.

This study was initiated in response to declining estuarine wading bird and sportfish populations in an area of northeast Florida Bay subject to inflow from the intensively managed freshwater C-111 canal system. The



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study follows up a recently completed benthic community study in the same area (Montague et al, 1989). Changes in the distribution, timing and volume of water inflows to the area and subsequent changes in hydroperiod have been linked to drastic declines in bird populations (National Audubon Society, unpublished data, 1989). Sportfish population decreases in recent years have been attributed to salinity stress for spotted sea trout in Everglades National Park (Rutherford et al 1989). Problems attributed to C-111 Canal include alteration of the salinity pattern of northeast Florida Bay leading to unnatural cycles of both reduced and hyper-saline conditions. Specific actions identified in the recently completed Surface Water Improvement and Management Plan for the Everglades (SWIM Plan) call for an analysis of fish species that use Florida Bay, with respect to their salinity requirements. This will aid activities aimed at preservation of the estuary as a forage habitat for birds and a habitat for aquatic organisms (eg. American crocodile, sportfish) (SFWMD 1989).

For purposes of this study, northeastern Florida Bay is defined as the area east of the central Florida Bay bank system and north of the Key Largo Ranger Station, Everglades National Park. In contrast to the rest of Florida Bay, this area is usually characterized by salinity gradients during the wet season (June through November) from low salinities (eg. 0 to 5 ppt) at northern locations, to higher values (eg. 30 to 35 ppt) at southern locations (Schmidt 1979).

This general area has been divided into two systems for design and analysis in this study. The eastern-most creek/bay system (Highway Creek/Little Blackwater Sound/Blackwater Sound) is directly downstream from C-111 Canal, whereas the western system (Snook Creek/Mid-northeast Florida Bay/Buttonwood Sound) is presumably less influenced by managed flows (Tabb 1967, and South Florida Water Management District, unpublished data).

The primary question considered in this report is: Can salinity regime be controlled to the benefit of desirable sportfish juveniles and forage base species in managing freshwater inflow to an estuary? This study is designed to determine differences in abundance and species composition of fish communities in mangrove habitat that occur with time along a salinity gradient. Conditions suitable for the occurrance of juvenile sportfish (eg. gray snapper) and forage fish (eg. killifish) relative to salinity and other environmental variables will also be identified. Ecological theories concerning the effects of salinity on fish in biological systems will be considered in interpreting the results of this study.

From a broad ecological perspective, estuarine fish inhabitants have been categorized as transients and residents depending on whether they spawn within or outside the estuary (Gunter 1967, Kikuchi 1974, Yanez-Arancibia et al 1980). Important questions from a water management perspective are: Does the salinity regime of northeast



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Florida Bay provide an advantage for one or the other of these groups? Does the fish community remain relatively stable in terms of abundance and species composition throughout salinity transition periods or do these factors vary with salinity conditions? Does this information indicate that a relationship exists between salinity regime and production of transient fish in this semi-tropical estuary?

These questions have remained unexplored for this area. Review of studies for the coastal region including Everlades National Park and Biscayne Bay, has revealed the existance of fifteen systematic fish sampling studies. Of these, two included study sites in the area encompassed by this study (Schmidt 1979, Funicelli et al 1986). Only one study, concentrating on western Florida Bay, focused on red mangrove prop root habitat (Thayer et al. 1987).

Of the fifteen local studies reviewed, four were conducted only in areas where relatively stable marine salinities prevailed (Thayer et al 1979, Weinstein 1977, Springer and McErlean 1962, Brook 1977). Another four were conducted only in areas where salinity levels varied greatly from almost fresh to intermediate (20 to 30 ppt) (Roessler 1970, Odum 1971, Clark 1971, Tabb et al 1962, Browder et al 1986).

The remaining seven of the fifteen studies included sites in areas where both variable and stable salinity regimes occurred (Schmidt 1979, Sogard et al 1987, Sogard et



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al 1989, Funicelli et al 1986, Thayer et al 1987, Lindall et al 1973, Carter et al 1973). Of these latter seven studies, none included an analysis of fish communities and abundances specifically comparing variable and stable salinity locations.

Thus, this study will provide a unique perspective by deliberately sampling and identifying fish community differences across the salinity gradient which seasonally occurs in this part of Florida Bay. Such a design will help identify community factors attributable to salinity alone.

As a general study approach, three methods of sampling fish are being used to compare upstream, mid-stream, and downstream locations across a salinity variation gradient. Statistical comparisons of measurable community composition and abundance factors over time and space will be made. Variation in mean salinity and community composition should be evident as the dry season changes to wet and vice versa.

## MATERIALS AND METHODS

### LOCATIONS

A balanced analysis of variance design with two creek systems and three salinity regimes is being used to determine if differences occur in fish community composition across a salinity gradient. This geographic design encompasses three salinity variability regimes across a gradient from low-mean/high-variability salinities for

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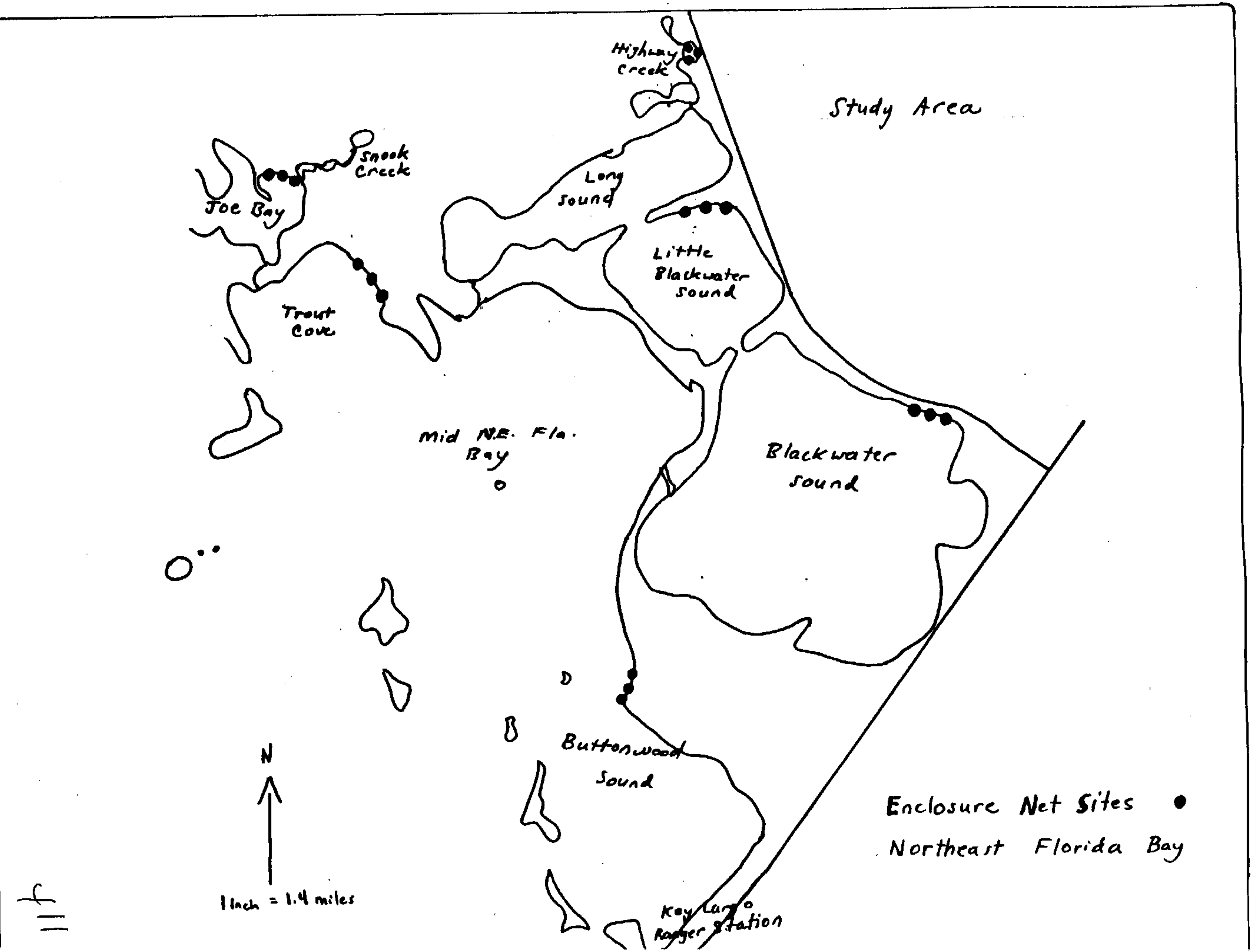
upstream stations, to mid-mean/mid-variability salinities for mid-stream stations, to high-mean/low-variability salinities for downstream stations (Montague et al 1989; Ley and Montague 1989).

The design includes two creek/bay systems (eastern and western), each containing a creek that carries freshwater to the eastern Florida Bay area, a bay downstream from the creek but still measurably affected by freshwater inflow, and an outer bay much less affected by freshwater inflow but more by oceanic influences. The two systems sampled should generally replicate the salinity/geographic gradient. Differences found between the two systems may be attributable to water management of the C-111 Canal. The upstream stations, Snook Creek (western) and Highway Creek (eastern), deliver freshwater to eastern Florida Bay. Mid-northeast Florida Bay (west) and Little Blackwater Sound (east) represent the mid Bay locations. To the outer stations (Buttonwood Sound-west and Blackwater Sound-east), Atlantic Ocean and Gulf of Mexico waters are delivered through Manatee and Jewfish Creeks (east) and Tavernier Creek (and others) in the west.

The presence of juvenile sportfish that use the estuary as a nursery should be evident at these stations over a year's period. A part of the rationale for selecting these sites is to follow the progress of these juveniles up the estuary if such a distribution change occurs in response to changing salinity.


Enclosure Net Sites
Northeast Florida Bay
Study Area
Highway Creek
Snook Creek
Joe Bay
Long Sound
Little Blackwater Sound
Trout Cove
Blackwater Sound
Mid N.E. Fla. Bay
Buttonwood Sound
Key Largo Ranger Station
N
1 Inch = 1.4 miles

SAMPLING METHODS

A pilot study testing eight visual and collecting methods began in November 1988, and ended in March 1989 (Ley and Montague 1989). The pilot study objective was to determine the most effective methods for sampling in mangrove prop roots across the study area. The three visual methods tested were 35 mm photography, underwater video, and snorkeling with underwater data sheets. Collecting methods tested included minnow traps, large traps, gill nets, pull-up nets, and enclosure nets with rotenone (Ley and Montague, 1989).

Visual methods provided consistent data on abundance and taxa for larger, curious, and distinctive fish under conditions of favorable visibility, water depth and wind. While visual censusing is effective, the turbidity and variable depths at mangrove root edges limits its usefulness in upstream habitats.

Of the trapping and collecting methods, minnow traps and enclosure nets were found to be the most feasible and effective. These methods complement the visual methods by sampling the benthic and cryptic species.

Thus, based on feasibility and effectiveness, three methods are being used to sample the fish communities in the six general locations (two creek x three salinity regimes):

| Method | Stations | Replicates | Repetitions |
| --- | --- | --- | --- |
| Enclosure net | 6 | 3 | 12 |
| Minnow traps | 6 | 32 | 12 |
| Snorkeling | 6 | 4 | 12 |

ENCLOSURE NET

For each location, three enclosure nets (30.5 m in length) are being employed with rotenone on each sampling date. This methodology is analogous to that of Thayer et al. (1987). Sites chosen for net deployment are protected from the prevailing southeast wind, have greater than 20 cm mean water depth at the prop root edge, and have a berm exposed at high tide along the interior edge. The water depth requirement is intended to provide some uniformity among the sites in terms of volume of water enclosed. The berm provides a bank beyond wich fish cannot escape when rotenone is applied within the net (see below).

Initially, the sites were prepared by cutting two one-foot wide paths perpendicular to the shoreline back into the roots. The six millimeter mesh nylon seine is deployed by two persons who carry it, scrolled round two wooden dowels, to the mid-point between the two paths. They wade in opposite directions parallel to the edge, unrolling the net, and walking up the paths. The net is staked down at the upper end of the path, the bottom chain tamped down along the entire edge, and the top edge hung over several PVC



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poles (to prevent fish from jumping over the net). All three nets are set in similar fashion.

Liquid rotenone is then being applied within the enclosed area. Fish which immediately begin to surface, are collected using hand nets for 30 to 45 minutes. After repeating the process at the other three sites, and allowing the rotenone to dissipate, a snorkeler retrieves sunken fish from within each enclosure. Fish and invertebrates collected are being identified and measured to total and standard (or carapace) length.

Other environmental measures taken for each sample include water depth, salinity, temperature, wind speed, wind direction, time of day, and air temperature. Mangrove root density and tree height will be determined for each site one time during the study.

MINNOW TRAPS

The design for minnow trap sampling is directly coordinated with the snorkeling stations. One trap is set at each of the snorkeling stations making a total of eight traps per site. The unbaited, five millimeter mesh, metal traps are placed far back into the mangrove edge and remain in place for 24 to 48 hours. A snorkel sample is made during this period (see below). Organisms collected in the traps are identified and measured.

SNORKELING

The mangrove edge was marked with flagging every 10 meters along an 80 meter edge. Four transects are located in each general location (eg. Little Blackwater Sound).

To conduct the survey, the snorkeler(s) approach the flagged edge and remain stationary under each flag for 30 seconds, and record on underwater data sheets, the species, sizes and numbers of fish observed. Maximum distance of visibility is measured horizontally using a white push pole and line. Salinity, temperature, water depth, types of grass and algae present and other environmental parameters are measured with each sample taken. One time during the study, the depth and density of roots will be determined for each station. Twice during the study, seagrass samples will be taken at adjacent sites for determination of species composition, canopy height, shoot density and biomass.

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## RESULTS

### MINNOW TRAPS AND SNORKELING

Due to time constraints, no new minnow trap and snorkeling data have been analyzed. Results presented in the pilot study are summarized below.

Pilot study results for minnow trap samples indicated that 21 species of fish were captured. No differences in species richness were found in upstream versus downstream locations.

In contrast, distinct patterns were noted for the snorkeling samples (8 stations along 80 meter transects). A total of 32 taxa were recorded, averaging five taxa per sample upstream, seven taxa mid-stream, and nine taxa downstream.

Relative abundances by taxa varied spatially. Most abundant visually-sampled taxa upstream were *Cichlasoma urophthalmus* (an introduced exotic), silversides (*Atherinidae*), and gray snapper (*Lutjanus griseus*). Mid-stream, the taxa found in greatest abundance included gray snapper, silversides, and mojarras (*Gerreidae*). Downstream, most abundant were silversides, blue-striped grunt (*Haemulon sciurus*), gray snapper and mojarras. Relative abundance of taxa collected in minnow traps were dominated by *Cichlasoma urophthalmus* upstream, and by *Lucania parva* mid- and downstream.

The two methods seem to sample portions of the population which differ in spatial heterogeneity. In terms of species composition, the more benthic and cryptic species sampled using the minnow traps appear to vary less across the geographic area sampled than the water column species sampled visually. This pattern appears to be consistent in the first months of data collected under the full scale study (underway since May).

ENCLOSURE NETS

The following results represent the first analysis of the enclosure net findings. Further analysis of these data will occur further in Phase 2. Most importantly, it should be noted that abundances reported here are for an average-sized enclosure net area of 130 square meters; the actual area of each site enclosed is yet to be measured in the field. Detailed area and topographic information for each site will be determined for all sites (including prop root density, sediment types and other physical features).

Presented in this report are analyses of data collected during the first six months of the study. Included are net efficiency test results as well as abundance, species composition, and number of species per net sample data. Salinity data is also analyzed on a preliminary basis for the first six months.

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## Net Efficiency Tests: Results and Discussion

The purpose of conducting net efficiency tests is to obtain an estimate of sampling effectiveness. The method used in these tests was to conduct a mark-recapture study using the normal net procedures.

Several minnow traps were placed inside the area to be enclosed on the day before net deployment. After the net was in place, the minnow traps were removed and cleared and the fish placed into buckets. Fish were measured, fin-clipped, and returned to the enclosed net area in minimal time. At least 30 fish were used per net in the test. This process was repeated at all three net locations per sampling day. Procedures for rotenone application, initial dip-netting, and same-day snorkel recovery were the same as described above. In addition, we tested the advantages of leaving the nets in place overnight and collecting fish the next day (next-day snorkel).

Seven tests were conducted spanning the upper, middle, and downstream locations. Four-hundred and ninety-two fish were marked and an average of 18.7 percent were recovered in the initial dip-net recovery (Table 1). By adding the same-day snorkel procedure, efficiency increased by 8.3 percent. The mean recovery rate was increased to 38 percent by leaving the nets up overnight and collecting the next day. The maximum recovery rate was 72.4 percent, which occurred at Southeast Trout Cove (Table 1).

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TABLE 1. PRELIMINARY EFFICIENCY TEST RESULTS

NUMBER OF FISH RECOVERED BY COLLECTION EFFORT

Table 1a. Abundance of clipped fish recovered

| Stations | Number of fish Fin-clipped | Marked Fish Recovered A Initial Dip net | B First snorkel | C Second snorkel | Total Percent |
|---|---|---|---|---|---|
| Buttonwood west | 83 | 5 | 3 | 2 | 10 |
| Buttonwood east | 67 | 4 | 6 | 1 | 11 |
| Buttonwood mid | 76 | 14 | 7 | 8 | 29 |
| SE Trout Cove | 76 | 27 | 9 | 19 | 55 |
| Mid Trout Cove | 77 | 18 | 5 | 28 | 51 |
| NE Trout Cove | 81 | 11 | 2 | 0 | 13 |
| Highway Ck east | 32 | 9 | 5 | 0 | 14 |
| TOTAL | 492 | 88 | 37 | 58 | 183 |

Table 1b. Percent of clipped fish recovered.

| | Number of fish Fin-clipped | Marked Fish Recovered A Initial Dip net | B First snorkel | C Second snorkel | Total Percent |
|---|---|---|---|---|---|
| Buttonwood west | 100 | 6.0 | 3.6 | 2.4 | 12.0 |
| Buttonwood east | 100 | 6.0 | 9.0 | 1.5 | 16.4 |
| Buttonwood mid | 100 | 18.4 | 9.2 | 10.5 | 38.2 |
| SE Trout Cove | 100 | 35.5 | 11.8 | 25.0 | 72.4 |
| Mid Trout Cove | 100 | 23.4 | 6.5 | 36.4 | 66.2 |
| NE Trout Cove | 100 | 13.6 | 2.5 | 0.0 | 16.0 |
| Highway Ck east | 100 | 28.1 | 15.6 | 0.0 | 43.8 |
| MEAN | 100.0 | 18.7 | 8.3 | 10.8 | 37.9 |
| ST. DEVIATION | 0.0 | 10.3 | 4.3 | 13.3 | 22.8 |

Table 1c. Percent of clipped fish recovered, calculated cumulatively by method of collection.

| | | Dip Net only | Dip Net with 1st Snorkel | Dip Net with 1st and 2nd Snorkel |
|---|---|---|---|---|
| Buttonwood west | 100 | 6.0 | 9.6 | 12.0 |
| Buttonwood east | 100 | 6.0 | 14.9 | 16.4 |
| Buttonwood mid | 100 | 18.4 | 27.6 | 38.2 |
| SE Trout Cove | 100 | 35.5 | 47.4 | 72.4 |
| Mid Trout Cove | 100 | 23.4 | 29.9 | 66.2 |
| NE Trout Cove | 100 | 13.6 | 16.0 | 16.0 |
| Highway Ck east | 100 | 28.1 | 43.8 | 43.8 |
| MEAN | 100.0 | 18.7 | 27.0 | 37.9 |
| ST. DEVIATION | 0.0 | 10.3 | 13.5 | 22.8 |
| MIN | | 6.0 | 9.6 | 12.0 |
| MAX | | 35.5 | 47.4 | 72.4 |

To examine the variation in recovery rate, we analyzed corresponding conditions and other factors. In one test (Northeast Trout Cove), three additional persons were used in the inital dip-netting making a total of five. Surprisingly, this made no difference in the relative recovery rate (Table 1). When the nets were left in place overnight, at some sites crabs had removed the fins of fish recovered, so that clipped fish could not be distinguished. In such cases, we used a conservative estimate in the analysis. In one case, the net remained in place for two days (Highway Creek East). All fish recovered on the second day were unidentifiable (ie. clipped, unclipped) due to deterioration.

All tests were conducted under very similar conditions of temperature, time, mean water depth, sediment type (fine white clay) and salinity (except Highway Creek) (Table 2). No correlation is apparent between number of fish recovered and number captured in the total sample (Table 2). The only factor examined that seems to have a significant effect on the percent recovery is wind direction. If winds are blowing on to the site, recovery rate was below average in two out of three cases, even at low speeds (six and ten mph). The turbulence associated with windy conditions may effect the rotenone effectiveness or other factors in the sampling process.

Overall, a greater percentage of larger fish were recovered (7.5 to 15 cm) than smaller (Table 3). In fact,

TABLE 2. PRELIMINARY EFFICIENCY TEST RESULTS

Percent of clipped fish recovered and corresponding conditions.

| Station | Percent of total fish marked, recovered | Time of Day | Initial Wind Speed mph | Initial Wind Direction (on to/ away from station) | Conditions Air temp F | Conditions Water temp C | Conditions Salinity ppt | Mean Depth cm | Total abundance of fish sampled |
|---|---|---|---|---|---|---|---|---|---|
| Buttonwood west | 12 | 830 | 6 | on to | 79 | 26 | 41 | 60 | 540 |
| Buttonwood east | 16 | 900 | 10 | on to | 80 | 26 | 41 | 73 | 251 |
| Buttonwood Mid | 38 | 940 | 6 | on to | 79 | 26 | 41 | 65 | 761 |
| SE Trout Cove | 72 | 830 | 11 | away from | 82 | 26 | 40 | 57 | 946 |
| Mid Trout Cove | 66 | 930 | 11 | away from | 83 | 25 | 43 | 49 | 288 |
| NE Trout Cove | 16 | 1030 | 5 | away from | 84 | 27 | 40 | 55 | 951 |
| Highway Ck east | 44 | 835 | 3 | away from | 85 | 28 | 22 | 33 | 113 |

TABLE 3. PRELIMINARY EFFICIENCY TEST RESULTS

ABUNDANCE OF RECOVERED FISH BY SIZE CLASS

| SIZE CLASS (cm) | ABUNDANCE FIN-CLIPPED FISH | PERCENT ABUNDANCE RECOVERED |
|---|---|---|
| 2.5 to 5.0 | 369 | 35.8 |
| 5.0 to 7.5 | 98 | 35.7 |
| 7.5 to 15.0 | 25 | 68.0 |
| Total | 492 | 37.4 |

the methods were twice as efficient for the larger- sized group (68 percent). This may account for the differences we observed in comparison with the Thayer et al (1987) study using this method in which a mean recovery rate of 75 percent was acheived. Silver jenny (E. gula) was the primary species used in those tests, while goldspotted killifish (F. carpio) dominated the tests reported in this effort. On a species-specific basis, we recoverd 52 percent of the clipped E. gula and 32 percent of the F. carpio we had clipped (Table 4). Other investigators have found fish size to be a limiting factor in fish recovery rates following rotenone application (Bayley and Austen 1988). Weinstein and Davis (1980) reported significantly lower recoveries of fish smaller than 4.0 cm (11.5 percent to 46.7 percent) than fish over 4.0 cm (52.7 percent to 66.7 percent) from tidal creeks in North Carolina.

The results of these tests indicate a great deal of variation in recoverability among the species, more so than among the size groups. With more data from follow-up tests, adjustments can be made in the raw data to correct abundance estimates on a species-specific basis (Neilson and Johnson 1983).

Clearly, however, the larger species (eg. Strongula notata, F. grandis, E. gula) are more effectively sampled. No very large fish were used in the tests. In actual samples with the nets, we have sampled fish as large as 40 cm in standard length. We would expect an optimum size



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TABLE 4.
ABUNDANCE OF REOVERED FISH BY SPECIES

| SPECIES | ABUNDANCE FIN-CLIPPED FISH | PERCENT ABUNDANCE RECOVERED |
|---|---|---|
| Floridychthys carpio | 303 | 31.7 |
| Poecillia latipinnia | 95 | 55.8 |
| Lucania parva | 26 | 11.5 |
| Eucinostomus gula | 25 | 52.0 |
| Cyprinodon variegatus | 14 | 7.1 |
| Eucinostomus harengulus | 9 | 33.3 |
| Fundulus grandis | 8 | 75.0 |
| Fundulus confluentus | 4 | 0.0 |
| Strongula notata | 2 | 100.0 |
| Cichlasoma urophthalmus | 2 | 0.0 |
| Gambusia sp. | 1 | 100.0 |
| Opsanus beta | 1 | 0.0 |
| Atherinomorus stipes | 1 | 0.0 |
| Gerres cinereus | 1 | 0.0 |
| Total | 492 | 36.2 |

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range for this type of sampling process to occur for fish between 7.5 and 30.0 cm.

With regard to number of species recovered, we retreived a mean of two-thirds of the species clipped per sample. The initial dip-net sample recovered most of the species, with further collecting adding little more in terms of additional species (Table 5).

In conclusion, the net efficiency tests reveal species-specific and size class biases. Fish over 7.5 cm standard length are more efficiently sampled. Species with above average recovery rates and more than five examples were: sailfin mollies (*P. latipinnia*), silver jenny (*E. gula*), and gulf killifish (*F. grandis*). Very low recovery rates were found for rainwater killifish (*L. parva*) and sheepshead minnow (*C. variegatus*).

These tests also reveal the probable negative effect of winds onto the sampling sites. The effect of temperature on the effectiveness of the methods was not evaluated. When temperature decreases significantly in the area, these tests will be repeated since this factor probably significantly effects the procedure (Thayer et al 1987).

Finally, the test results indicate that most of the species occurring at the sites are collected in the initial dip-net collections. Abundance estimates, however, are

TABLE 5. PRELIMINARY EFFICIENCY TEST RESULTS

NUMBER OF SPECIES RECOVERED

| Station | Number of Species Fin-clipped | Marked Fish Recovered A Initial Dip net | B Same day snorkel | C Next day snorkel | Total Percent |
|---|---|---|---|---|---|
| Buttonwood west | 7 | 3 | 0 | 1 | 57.1 |
| Buttonwood east | 3 | 1 | 0 | 0 | 33.3 |
| Buttonwood mid | 7 | 3 | 2 | 0 | 71.4 |
| SE Trout Cove | 4 | 4 | 0 | 0 | 100.0 |
| Mid Trout Cove | 7 | 3 | 1 | 0 | 57.1 |
| NE Trout Cove | 7 | 5 | 0 | 0 | 71.4 |
| Highway Ck east | 5 | 4 | 0 | 0 | 80.0 |
| Average | 5.7 | 3.3 | 0.4 | 0.1 | 67.5 |
| Stand. deviation | 1.6 | 1.2 | 0.7 | 0.3 | 19.4 |

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greatly improved by including the same day snorkel (8.3 percent) and a next day snorkel (10.8 percent). Expected efficiency rates from all collection methods were as high as 72.4 percent.

## Preliminary Net Enclosure Study Results

Following the study design, graphs of salinity data, and analysis of variance for total abundances and number of species are presented across the three types of locations: upstream, mid-stream and downstream. A second set of analyses is presented for the eastern versus western systems to determine if significant differences are observed.

### Results: Salinity

Upstream salinity ranged from over 30 ppt during June (month 2) to near zero during August (month 4, Figure 1a). Mid-stream salinity ranged from 20 ppt during September (month 5) to over 40 ppt in November (Figure 1b). Downstream, ranged from 30 ppt in May to over 40 ppt in November (Figure 1c).

Overall, higher salinity levels occurred in the western system (Snook Creek/Mid-northeast Florida Bay/Buttonwood Sound) than the eastern system (Highway Creek/Little Blackwater Sound/Blackwater Sound) (Figure 2). The eastern system is more greatly impacted by the C-111 Canal.

Figure 1a. Upstream Salinity

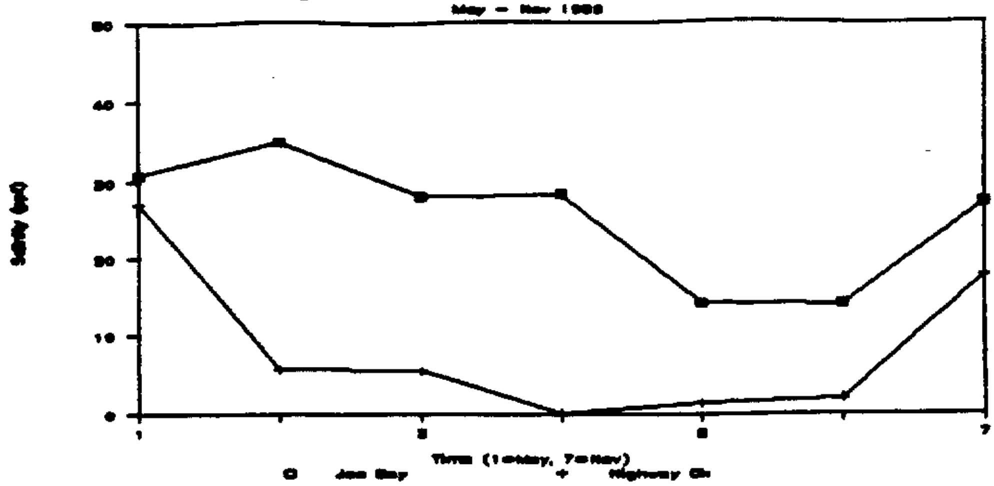

Figure 1b. Midstream Salinity

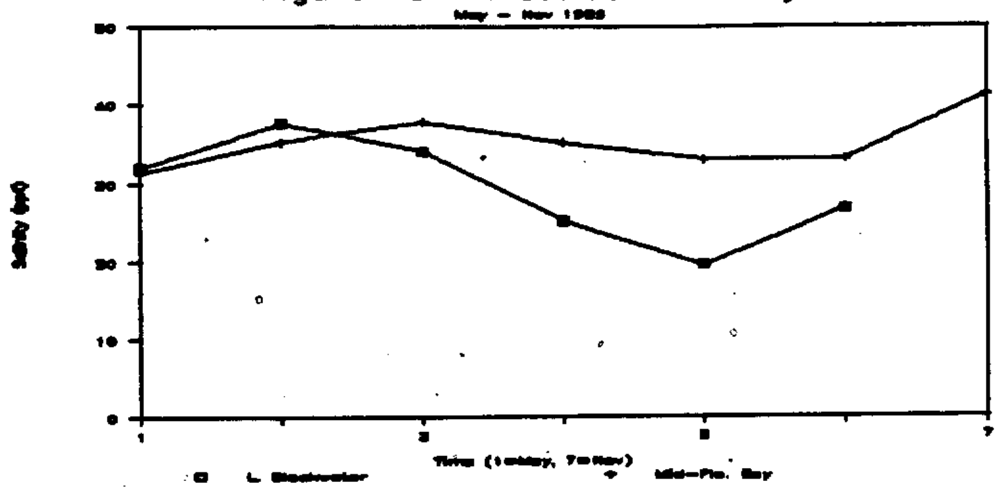

Figure 1c. Downstream Salinity

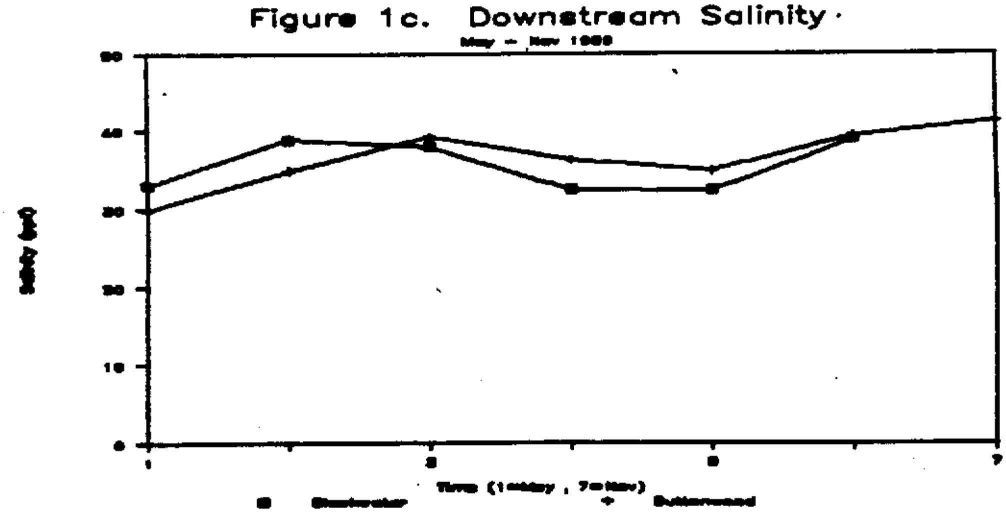

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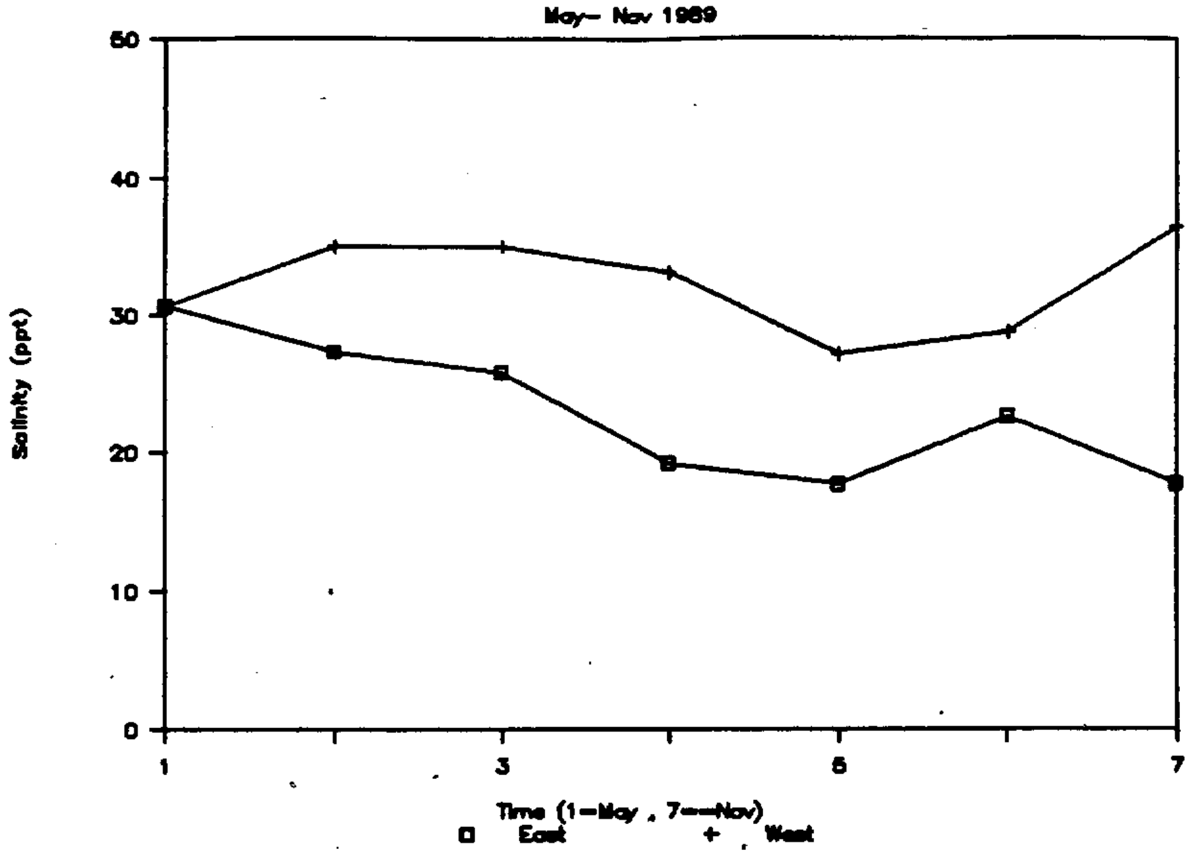
Figure 2. East and West System Salinity

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## Results: Number of Species per Net Sample

Averaged over all net samples, the mean number of fish species was eleven per net, ranging from six to seventeen (Table 6). When averaged over the study period, mid-stream locations were significantly greater species richness (12 species per net) than up-stream (11 species) or down-stream locations (10 species) ($n=102, p<.01$) (Table 6). Monthly differences, however, were not statistically significant.

Differences in mean number of species over the study period were significantly greater in the western system (12 fish species) than the eastern (10.6 ) (Table 7). The t-test results indicated significant east/west differences in 5 of the 6 sampling months (July being the exception).

## Results: Abundance

An average of 315 fish were collected per net (range 26 to 2500) over the study period (Table 8). A preliminary estimate of density was obtained by dividing the number of fish per net by an estimate of the enclosure area based on the length of the net. If the net forms a half circle with the shoreline as one side, the enclosed area would be 130 square meters. Refinement of these calculations will be made when the actual area enclosed at each station is measured in the field. Using a 130 square meter estimate,



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TABLE 6
NUMBER OF SPECIES
TEST FOR UP, MID AND DOWNSTREAM DIFFERENCES AMONG MEANS
ANALYSIS OF VARIANCE

Untransformed data for comparison
May to October 1989: Big Nets

| | May No. Species | June No. Species | July No. Species | August No. Species | September No. Species | October No. Species | AVERAGE NO. SPECIE |
|---|---|---|---|---|---|---|---|
| UPSTREAM LOCATIONS | | | | | | | |
| Highway Creek East | 8 | 8 | 12 | 9 | 8 | 6 | 8.5 |
| Highway Creek Island | | 9 | 9 | 11 | 8 | 12 | 8.2 |
| Highway Creek West | 7 | 8 | 14 | 8 | 11 | 7 | 9.2 |
| Joe Bay East | 15 | 15 | 11 | 15 | 16 | 14 | 14.3 |
| Joe Bay Mid | 8 | 13 | 15 | 14 | 18 | 16 | 14.0 |
| Joe Bay West | | 8 | 13 | 14 | 12 | 15 | 10.3 |
| UPSTREAM MEAN | 10 | 10 | 12 | 12 | 11 | 12 | 11 |
| MID LOCATIONS | | | | | | | |
| Little Blackwater Sound East | 13 | 7 | 14 | 14 | 15 | 14 | 12.8 |
| Little Blackwater Sound Mid | 12 | 7 | 16 | 12 | 11 | 15 | 12.2 |
| Little Blackwater Sound West | | 16 | 12 | 11 | 13 | 16 | 11.3 |
| Trout Cove Mid | | 11 | 15 | 13 | 13 | 17 | 11.5 |
| Trout Cove NE | 10 | 9 | 9 | 9 | 11 | 14 | 10.3 |
| Trout Cove SE | 8 | 12 | 13 | 8 | 10 | 14 | 10.8 |
| MIDSTREAM MEAN | 11 | 10 | 13 | 11 | 12 | 15 | 12 |
| DOWNSTREAM LOCATIONS | | | | | | | |
| Blackwater Sound Far from Gilberts | 11 | 9 | 10 | 8 | 11 | 17 | 11.0 |
| Blackwater Sound Mid | | 11 | 7 | 12 | 9 | 16 | 9.2 |
| Blackwater Sound Near Gilberts | 12 | 13 | 10 | 6 | 5 | 11 | 9.5 |
| Buttonwood Mid | | 11 | 9 | 10 | 6 | 12 | 8.0 |
| Buttonwood NE (nr Boggies) | 14 | 15 | 12 | 13 | 10 | 13 | 12.8 |
| Buttonwood SW (nr Point) | 17 | 9 | 8 | 9 | 7 | 11 | 10.2 |
| DOWNSTREAM MEAN | 14 | 11 | 9 | 10 | 8 | 13 | 10 |
| OVERALL MEAN | 11 | 11 | 12 | 11 | 10 | 13 | 11 |
| SIGNIFICANT | NO | NO | NO | NO | NO | NO | YES OVERAL |

TABLE 7
NUMBER OF SPECIES
TEST FOR SIGNIFICANT DIFFERENCES BETWEEN EAST AND WEST SYSTEMS:
T-TEST RESULTS

Species data
May to October 1989: Big Nets

| | May No. Species | June No. Species | July No. Species | August No. Species | Septembe No. Spec | October No. Species | AVERAGE NO. SPECIES MAY-OCT |
|---|---|---|---|---|---|---|---|
| WEST SYSTEMS | | | | | | | |
| Joe Bay East | 15 | 15 | 11 | 15 | 16 | 14 | 14.3 |
| Joe Bay Mid | 8 | 13 | 15 | 14 | 18 | 16 | 14.0 |
| Joe Bay West | | 8 | 13 | 14 | 12 | 15 | 12.4 |
| Trout Cove NE | 10 | 9 | 9 | 9 | 11 | 14 | 10.3 |
| Trout Cove Mid | | 11 | 15 | 13 | 13 | 17 | 13.8 |
| Trout Cove SE | 8 | 12 | 13 | 8 | 10 | 14 | 10.8 |
| Buttonwood NE (nr Boggies) | 14 | 15 | 12 | 13 | 10 | 13 | 12.8 |
| Buttonwood Mid | | 11 | 9 | 10 | 6 | 12 | 9.6 |
| Buttonwood SW (nr Point) | 17 | 9 | 8 | 9 | 7 | 11 | 10.2 |
| EAST SYSTEMS | | | | | | | |
| Highway Creek East | 8 | 8 | 12 | 9 | 8 | 6 | 8.5 |
| Highway Creek Island | | 9 | 9 | 11 | 8 | 12 | 9.8 |
| Highway Creek West | 7 | 8 | 14 | 8 | 1 | 7 | 7.5 |
| Little Blackwater Sound East | 13 | 7 | 14 | 14 | 15 | 14 | 12.8 |
| Little Blackwater Sound Mid | 12 | 7 | 16 | 12 | 11 | 15 | 12.2 |
| Little Blackwater Sound West | | 16 | 12 | 11 | 13 | 16 | 13.6 |
| Blackwater Sound Near Gilber | 12 | 13 | 10 | 6 | 5 | 11 | 9.5 |
| Blackwater Sound Mid | | 11 | 7 | 12 | 9 | 16 | 11.0 |
| Blackwater Sound Far from Gi | 11 | 9 | 10 | 8 | 11 | 17 | 11.0 |
| ALL DATA MEAN | 11.25 | 10.61 | 11.61 | 10.89 | 10.22 | 13.33 | 11.3 |
| WEST STATION MEAN | 12.00 | 11.44 | 11.67 | 11.67 | 11.44 | 14.00 | 12.0 |
| EAST STATION MEAN | 10.50 | 9.78 | 11.56 | 10.11 | 9.00 | 12.67 | 10.6 |
| SIGNIFICANT DIF. @ 95% | YES | YES | NO | YES | YES | YES | YES |

TABLE B
ABUNDANCE DATA
TEST FOR UP, MID AND DOWNSTREAM DIFFERENCES IN MEANS
ANOVA

Untransformed data presented
Note: natural log transformed data used for calculations
May to November 1989: Big Nets

| | May Abundance | June Abundance | July Abundance | August Abundance | September Abundance | October Abundance | AVERAGE ABUNDANCE |
|---|---|---|---|---|---|---|---|
| UPSTREAM LOCATIONS | | | | | | | |
| Highway Creek East | 146 | 342 | 573 | 173 | 100 | 62 | 233 |
| Highway Creek Island | | 414 | 227 | 111 | 74 | 782 | 322 |
| Highway Creek West | 126 | 81 | 307 | 53 | 50 | 26 | 107 |
| Joe Bay East | 182 | 467 | 160 | 86 | 233 | 162 | 215 |
| Joe Bay Mid | 170 | 546 | 171 | 147 | 133 | 102 | 212 |
| Joe Bay West | | 85 | 118 | 349 | 193 | 377 | 224 |
| UPSTREAM MEAN | 156 | 323 | 259 | 153 | 131 | 252 | 212 |
| MID LOCATIONS | | | | | | | |
| Little Blackwater Sound East | 984 | 51 | 134 | 83 | 238 | 1102 | 432 |
| Little Blackwater Sound Mid | 706 | 24 | 95 | 481 | 1172 | 2531 | 835 |
| Little Blackwater Sound West | | 68 | 72 | 54 | 138 | 294 | 125 |
| Trout Cove Mid | | 135 | 224 | 223 | 306 | 261 | 230 |
| Trout Cove NE | 29 | 85 | 64 | 252 | 383 | 284 | 183 |
| Trout Cove SE | 84 | 340 | 466 | 319 | 302 | 210 | 287 |
| MIDSTREAM MEAN | 451 | 117 | 176 | 235 | 423 | 780 | 364 |
| DOWNSTREAM LOCATIONS | | | | | | | |
| Blackwater Sound Far from Gilberts | 554 | 82 | 266 | 86 | 90 | 276 | 226 |
| Blackwater Sound Mid | | 259 | 112 | 181 | 166 | 777 | 299 |
| Blackwater Sound Near Gilberts | 367 | 193 | 283 | 67 | 48 | 400 | 226 |
| Buttonwood Mid | | 392 | 224 | 375 | 531 | 1738 | 652 |
| Buttonwood NE (nr Boggies) | 85 | 282 | 256 | 75 | 270 | 1426 | 399 |
| Buttonwood SW (nr Point) | 96 | 323 | 235 | 254 | 288 | 1700 | 483 |
| DOWNSTREAM MEAN | 276 | 255 | 229 | 173 | 232 | 1053 | 370 |
| OVERALL MEAN | 294 | 232 | 222 | 187 | 262 | 695 | 315 |
| SIGNIFICANT DIFFERENCES AT 95% LEVEL | NO | NO | NO | NO | NO | NO | YES OVERALL |

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the average fish density is 2.4 fish per square meter (range 0.2 to 19.2). Across the study period area and during the study period, abundance peaked in October at 695 fish per net. The lowest abundance per net occurred in August at 187 fish per net.

Of the upper, mid, and downstream locations, the downstream and mid-stream stations averaged 370 and 364 fish per net respectively. An analysis of variance indicated that the upstream stations had significantly lower fish densities at 212 fish per net ($n=102$, $p < .01$) than the mid and downstream stations.

Monthly abundance means did not differ significantly among the up-, mid- and downstream locations, but some trends were noted. The lowest mean monthly abundances occurred upstream most often (4 of the 6 months), but for the two exceptional months (June and July), the upstream stations had the highest mean abundances among the general locations. The mid-stream locations had the greater mean abundances in three of the six months, but were the lowest of the three gradient positions in June and July. The downstream locations fell between the other two in five of the six months.

Overall, both eastern and western systems had almost equal mean abundances per net (318 per net west and 315 per net east) (Table 9). However, on a monthly basis, the results of the t-test indicated that significant differences occurred between the two systems. For three of the four

TABLE 9
ABUNDANCE DATA
TEST FOR SIGNIFICANT DIFFERENCES BETWEEN EAST AND WEST SYSTEMS:
T-TEST RESULTS

Untransformed abundance data
May to October 1989: Big Nets

| | May Abundance | June Abundance | July Abundance | August Abundance | September Abundance | October Abundance | AVERAGE ABUNDANCE MAY-OCT |
|---|---|---|---|---|---|---|---|
| WEST SYSTEMS | | | | | | | |
| Joe Bay East | 182 | 467 | 160 | 86 | 233 | 162 | 215 |
| Joe Bay Mid | 170 | 546 | 171 | 147 | 133 | 102 | 212 |
| Joe Bay West | | 85 | 118 | 349 | 193 | 377 | 224 |
| Trout Cove NE | 29 | 85 | 64 | 252 | 383 | 284 | 183 |
| Trout Cove Mid | | 135 | 224 | 223 | 306 | 261 | 230 |
| Trout Cove SE | 84 | 340 | 466 | 319 | 302 | 210 | 287 |
| Buttonwood NE (nr Boggies) | 85 | 282 | 256 | 75 | 270 | 1426 | 399 |
| Buttonwood Mid | | 392 | 224 | 375 | 531 | 1738 | 652 |
| Buttonwood SW (nr Point) | 96 | 323 | 235 | 254 | 288 | 1700 | 483 |
| EAST SYSTEMS | | | | | | | |
| Highway Creek East | 146 | 342 | 573 | 173 | 100 | 62 | 233 |
| Highway Creek Island | | 414 | 227 | 111 | 74 | 782 | 322 |
| Highway Creek West | 126 | 81 | 307 | 53 | 50 | 26 | 107 |
| Little Blackwater Sound East | 984 | 51 | 134 | 83 | 238 | 1102 | 432 |
| Little Blackwater Sound Mid | 706 | 24 | 95 | 481 | 1172 | 2531 | 835 |
| Little Blackwater Sound West | | 68 | 72 | 54 | 138 | 294 | 125 |
| Blackwater Sound Near Gilber | 367 | 193 | 283 | 67 | 48 | 400 | 226 |
| Blackwater Sound Mid | | 259 | 112 | 181 | 166 | 777 | 299 |
| Blackwater Sound Far from Gi | 554 | 82 | 266 | 86 | 90 | 276 | 226 |
| ALL DATA MEAN | 294 | 232 | 222 | 187 | 262 | 695 | 316 |
| WEST STATION MEAN | 108 | 295 | 213 | 231 | 293 | 696 | 318 |
| EAST STATION MEAN | 481 | 168 | 230 | 143 | 231 | 694 | 315 |
| SIGNIFICANT DIF. @ 95% | YES | YES | NO | YES | YES | NO | YES |

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months for which significant differences were indicated, the western system was higher than the eastern system, differing by about 80 fish each month. During May, however, a difference of 372 fish occurred, with the eastern system dominating.

Results: Species Composition

Overall, 48 species of fish were collected in the enclosure net samples during the first six months of the study. Atherinomorus stipes (hardhead silverside) and Anchoa mitchelli (bay anchovy) were by far the most abundant species (Table 10). They were followed closely by two killifishes (Floridichthys carpio and Lucania parva). Patterns in species distribution over space and time are discussed below.

Spatial Distribution: Up, Mid and Downstream: Small schooling fishes found in the water column numerically dominated the collections in all locations over the period of study (Table 11). Menidia berylina (inland silverside) ranked first at the upstream stations, while A. mitchelli and A. stipes dominated the mid- and downstream locations, respectively.

Other dominant fishes were more uniformly distributed throughout the study area (Table 11). These included the



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TABLE 10.
MASTER SPECIES LIST

ALL MONTHS BIG NET MAY-OCT 1989

| SPECIES | | OVERALL ABUNDANCE |
|---|---|---|
| Atherinomorus stipes | hardhead silverside | 7388 |
| Anchoa mitchelli | bay anchovy | 6632 |
| Floridichthys carpio | goldspotted killifish | 4275 |
| Lucania parva | rainwater killifish | 3904 |
| Menidia beryllina | inland silverside | 2409 |
| Poecilia latipinna | sailfin molly | 2051 |
| Microgobius gulosus | clown goby | 1138 |
| Eucinostomus harengulus | mojarra | 736 |
| Eugerres plumieri | striped mojarra | 597 |
| Strongula notata | redfin needlefish | 540 |
| Cichlasoma urophthalmus | mayan cichlid | 537 |
| Gambusia sp. | mosquito fish | 435 |
| Eucinostomus gula | silver jenny | 288 |
| Opsanus beta | gulf toadfish | 267 |
| Gobiosoma robustum | code goby | 216 |
| Lophogobius cyprinoides | crested goby | 146 |
| Gobiosoma bosci | naked goby | 126 |
| Gerres cinereus | yellowfin mojarra | 113 |
| Sphyraena barracuda | great barracuda | 78 |
| Lutjanus griseus | gray snapper | 59 |
| Fundulus confluentus | marsh killifish | 52 |
| Syngnathus scovelli | gulf pipefish | 38 |
| Fundulus grandis | gulf killifish | 32 |
| Cyprinodon variegatus | sheepshead minnow | 29 |
| Trinectes maculatus | hog choaker | 29 |
| Mugil cephalus | striped mullet | 23 |
| Mugil curema | white mullet | 23 |
| Eucinostomus melanopterus | flagfin mojarra | 19 |
| Ogilbia cayorum | key brotula | 15 |
| Guntherichthys longipenis | gold brotula | 6 |
| Chasmodes saburrae | Florida blenny | 5 |
| Syngnathus floridae | dusky pipefish | 5 |
| Belonesox belizanus | pike killifish | 4 |
| Opisthonema oglinum | Atlantic thread herring | 4 |
| Centropomus undecimalis | snook | 3 |
| Lobotes surinamensis | tripletail | 3 |
| Arius felis | sea catfish | 2 |
| Hippocampus zosterae | dwarf seahorse | 2 |
| Micrognathus criniger | fringed pipefish | 2 |
| Strongula marina | Atlantic needlefish | 2 |
| Gobiesox strumosus | skillet fish | 1 |
| Harengula jaguana | scaled sardine | 1 |
| Lepomis macrochirus | bluegill | 1 |
| Lucania goodei | bluefin killifish | 1 |
| Lutjanus apodus | schoolmaster | 1 |
| Rivulus marmoratus | rivulus | 1 |
| Strongula timucu | timucu | 1 |
| Trachinotus falcatus | permit | 1 |

TABLE 11.

COMBINED SPECIES LISTS FOR UP- MID- AND DOWNSTREAM LOCATIONS

ALL MONTHS BIG NET MAY-OCT 1989
Species and abundance.

| UPSTREAM | | MIDSTREAM | | DOWNSTREAM | |
|---|---|---|---|---|---|
| Anchoa mitchelli | 125 | Anchoa mitchelli | 6506 | Anchoa mitchelli | 1 |
| | | Arius felis | 1 | Arius felis | 1 |
| Atherinomorus stipes | 50 | Atherinomorus stipes | 378 | Atherinomorus stipes | 6960 |
| Belonesox belizanus | 3 | | | Belonesox belizanus | 1 |
| Centropomus undecimalis | 1 | Centropomus undecimalis | 2 | | |
| Chasmodes saburrae | 3 | | | Chasmodes saburrae | 2 |
| Cichlasoma urophthalmus | 537 | | | | |
| Cyprinodon variegatus | 24 | Cyprinodon variegatus | 3 | Cyprinodon variegatus | 2 |
| Eucinostomus gula | 1 | Eucinostomus gula | 240 | Eucinostomus gula | 47 |
| Eucinostomus harengulus | 146 | Eucinostomus harengulus | 507 | Eucinostomus harengulus | 82 |
| | | Eucinostomus havana | 1 | | |
| | | Eucinostomus melanopterus | 2 | Eucinostomus melanopterus | 17 |
| Eugerres plumieri | 426 | Eugerres plumieri | 172 | | |
| Floridichthys carpio | 1074 | Floridichthys carpio | 1620 | Floridichthys carpio | 1581 |
| Fundulus confluentus | 26 | Fundulus confluentus | 11 | Fundulus confluentus | 15 |
| Fundulus grandis | 11 | Fundulus grandis | 10 | Fundulus grandis | 11 |
| Gambusia sp. | 29 | Gambusia sp. | 211 | Gambusia sp. | 195 |
| Gerres cinereus | 10 | Gerres cinereus | 48 | Gerres cinereus | 55 |
| | | | | Gobiesox strumosus | 1 |
| Gobiosoma bosci | 124 | | | Gobiosoma bosci | 2 |
| Gobiosoma robustum | 166 | | | Gobiosoma robustum | 50 |
| | | | | Guntherichthys longipenis | 6 |
| | | | | Harengula jaguana | 1 |
| | | | | Hippocampus zosterae | 2 |
| Lepomis macrochirus | 1 | | | | |
| | | Lobotes surinamensis | 2 | Lobotes surinamensis | 1 |
| Lophogobius cyprinoides | 121 | Lophogobius cyprinoides | 24 | Lophogobius cyprinoides | 1 |
| Lucania goodei | 1 | | | | |
| Lucania parva | 792 | Lucania parva | 450 | Lucania parva | 2662 |
| Lutjanus apodus | 1 | | | | |
| Lutjanus griseus | 20 | Lutjanus griseus | 3 | Lutjanus griseus | 36 |
| Menidia beryllina | 1630 | Menidia beryllina | 413 | Menidia beryllina | 358 |
| | | | | Micrognathus criniger | 2 |
| Microgobius gulosus | 965 | Microgobius gulosus | 78 | Microgobius gulosus | 95 |
| Mugil cephalus | 9 | Mugil cephalus | 14 | | |
| | | Mugil curema | 21 | Mugil curema | 2 |
| | | | | Ogilbia cayorum | 18 |
| Opisthonema oglinum | 4 | | | | |
| Opsanus beta | 18 | Opsanus beta | 42 | Opsanus beta | 207 |
| Poecilia latipinna | 666 | Poecilia latipinna | 1166 | Poecilia latipinna | 219 |
| | | Rivulus marmoratus | 1 | | |
| Sphyraena barracuda | 4 | Sphyraena barracuda | 37 | Sphyraena barracuda | 37 |
| | | Strongula marina | 2 | | |
| Strongula notata | 203 | Strongula notata | 183 | Strongula notata | 154 |
| | | | | Strongula timucu | 1 |
| | | | | Syngnathus floridae | 8 |
| Syngnathus scovelli | 1 | Syngnathus scovelli | 22 | Syngnathus scovelli | 15 |
| | | Trachinotus falcatus | 1 | | |
| Trinectes maculatus | 3 | Trinectes maculatus | 26 | | |

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small benthic killifishes (L. parva and F. carpio) and the shallow water dwelling sailfin molly (Poecillia latipinnia).

More species were found downstream (36) than upstream (33), or midstream (32). In fact, 8 species were uniquely found in the downstream study locations, compared with 4 and 3 unique species up and mid stream respectively (Table 11). These unique species, however, were never among the more abundant fish species collected.

Some abundant upstream fishes were much less dominant in mid and downstream locations, including (Microgobius gulosus (clown goby), Cichlasoma urophthalmus (mayan cichlid), and Eugerres plumieri (striped mojarra) (Table 11).

Very abundant midstream species which were less dominant up and down were two other mojarras, Eucinostomus harengulus and Eucinostomus gula (silver jenny). Opsanus beta (gulf toadfish) was the only very abundant downstream species which was not abundant at up and mid stream locations (Table 11).

Spatial Distribution: East and West Systems: The eastern system dominant was Anchoa mitchelli with 6,470 fish collected (Table 12). In the western system, only 162 A. mitchelli were collected during the study period. A. stipes, while the most abundant species in the western system with 6,078 fish collected, was not as skewed in its distribution, with 1,310 also collected in the east.

TABLE 12.

COMBINED SPECIES LISTS FOR EAST AND WEST SYSTEMS

ALL MONTHS BIG NET MAY-OCT 1989
Species and abundance.

| EAST | | WEST | |
|---|---|---|---|
| Anchoa mitchelli | 6470 | Anchoa mitchelli | 162 |
| Arius felis | 1 | Arius felis | 1 |
| Atherinomorus stipes | 1310 | Atherinomorus stipes | 6078 |
| Belonesox belizanus | 1 | Belonesox belizanus | 3 |
| Centropomus undecimalis | 2 | Centropomus undecimalis | 1 |
| Chasmodes saburrae | 1 | Chasmodes saburrae | 4 |
| Cichlasoma urophthalmus | 471 | Cichlasoma urophthalmus | 66 |
| Cyprinodon variegatus | 9 | Cyprinodon variegatus | 20 |
| Eucinostomus gula | 29 | Eucinostomus gula | 259 |
| Eucinostomus harengulus | 415 | Eucinostomus harengulus | 320 |
| Eucinostomus havana | 1 | | |
| Eucinostomus melanopter | 18 | Eucinostomus melanopterus | 1 |
| Eugerres plumieri | 216 | Eugerres plumieri | 381 |
| Floridichthys carpio | 1398 | Floridichthys carpio | 2877 |
| Fundulus confluentus | 32 | Fundulus confluentus | 20 |
| Fundulus grandis | 14 | Fundulus grandis | 18 |
| Gambusia sp. | 210 | Gambusia sp. | 225 |
| Gerres cinereus | 78 | Gerres cinereus | 35 |
| Gobiesox strumosus | 1 | | |
| Gobiosoma bosci | 2 | Gobiosoma bosci | 124 |
| Gobiosoma robustum | 57 | Gobiosoma robustum | 159 |
| | | Guntherichthys longipenis | 6 |
| Harengula jaguana | 1 | | |
| Hippocampus zosterae | 2 | | |
| Lepomis macrochirus | 1 | | |
| Lobotes surinamensis | 1 | Lobotes surinamensis | 2 |
| Lophogobius cyprinoides | 41 | Lophogobius cyprinoides | 106 |
| Lucania goodei | 1 | | |
| Lucania parva | 2661 | Lucania parva | 1243 |
| | | Lutjanus apodus | 1 |
| Lutjanus griseus | 28 | Lutjanus griseus | 31 |
| Menidia beryllina | 973 | Menidia beryllina | 1437 |
| | | Micrognathus criniger | 2 |
| Microgobius gulosus | 725 | Microgobius gulosus | 413 |
| Mugil cephalus | 8 | Mugil cephalus | 15 |
| Mugil curema | 23 | | |
| | | Ogilbia cayorum | 15 |
| Opisthonema oglinum | 1 | Opisthonema oglinum | 3 |
| Opsanus beta | 152 | Opsanus beta | 115 |
| Poecilia latipinna | 261 | Poecilia latipinna | 1790 |
| Rivulus marmoratus | 1 | | |
| Sphyraena barracuda | 45 | Sphyraena barracuda | 33 |
| Strongula marina | 1 | Strongula marina | 1 |
| Strongula notata | 230 | Strongula notata | 310 |
| | | Strongula timucu | 1 |
| Syngnathus floridae | 4 | Syngnathus floridae | 1 |
| Syngnathus scovelli | 36 | Syngnathys scovelli | 2 |
| Trachinotus falcatus | 1 | | |
| Trinectes maculatus | 26 | Trinectes maculatus | 9 |

As with the up, mid and downstream comparison, the more benthic rainwater and goldspotted killifishes and the shallow water sailfin molly were abundant throughout both the eastern and western systems in northeast Florida Bay.

Forty species were collected in the west, while 44 species were found in the east. Two species uniquely occurred in the western stations, while six were unique to the east (Table 12). Both the bay anchovy and mayan cichlid were much more abundant in the eastern system than the west. In contrast, the striped mojarra and silver jenny were much more abundant in the west than the east.

Temporal Species Distribution: While actual abundance varied, the hardhead silverside (A. stipes) was a dominant species in five of the first six months of the study (Table 13). In October, the abundance of the hardhead silverside was 15 times greater than it was in May. The inland silversides (Menidia berylina) were also consistently abundant throughout the period (Table 13).

Changes in distribution over the first six months were analyzed on a preliminary basis by identifying which fish were very abundant (over 90 collected) during a given month in the up, mid and downstream locations (Tables 14a, 14b, and 14c).

At upstream locations, eight species were very abundant during at least one month of the study. Of these, only two species were consistently abundant over the period (ie.

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TABLE 13.

COMBINED SPECIES LISTS FOR MAY-OCTOBER 1989

ALL LOCATIONS
Species and abundance.

| | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER |
|---|---|---|---|---|---|---|
| Anchoa mitchelli | 1620 | 18 | 3 | 438 | 1007 | 3546 |
| Arius felis | | 1 | | | 1 | |
| Atherinomorus stipes | 341 | 25 | 504 | 297 | 920 | 5301 |
| Belonesox belizanus | | | | 1 | 2 | 1 |
| Centropomus undecimalis | 1 | | | | 1 | 1 |
| Chasmodes saburrae | | 3 | 1 | 1 | | |
| Cichlasoma urophthalmus | 1 | | | 9 | 32 | 495 |
| Cyprinodon variegatus | 5 | 9 | 7 | 1 | 1 | 6 |
| Eucinostomus gula | 11 | 13 | 15 | 11 | 20 | 218 |
| Eucinostomus harengulus | 100 | 68 | 115 | 65 | 130 | 258 |
| Eucinostomus melanopterus | | | 1 | | 5 | 13 |
| Euerres plumieri | | 30 | 115 | 89 | 229 | 134 |
| Floridichthys carpio | 133 | 543 | 1008 | 852 | 865 | 874 |
| Fundulus confluentus | 8 | 12 | 21 | 3 | 1 | 6 |
| Fundulus grandis | 5 | 3 | 2 | 6 | 2 | 14 |
| Gambusia sp. | 85 | 115 | 67 | 59 | 18 | 91 |
| Gerres cinereus | 7 | 8 | 8 | 22 | 25 | 43 |
| Gobiesox strumosus | | | | | 1 | |
| Gobiosoma bosci | 27 | 54 | 43 | 2 | | |
| Gobiosoma robustum | 56 | 54 | 48 | 33 | 19 | 6 |
| Harengula jaguana | 6 | | | | | 1 |
| Hippocampus zosterae | | 1 | | 1 | | |
| Lepomis macrochirus | | | | 1 | | |
| Lobotes surinamensis | | | 1 | 2 | | |
| Lophogobius cyprinoides | 23 | 28 | 45 | 24 | 16 | 10 |
| Lucania goodei | | | | | | 1 |
| Lucania parva | 745 | 888 | 722 | 496 | 340 | 713 |
| Lutjanus apodus | | | 1 | | | |
| Lutjanus griseus | 4 | 16 | 13 | 13 | 7 | 6 |
| Menidia beryllina | 96 | 1165 | 505 | 167 | 352 | 124 |
| Micrognathus criniger | 2 | | | | | |
| Microgobius gulosus | 27 | 571 | 239 | 139 | 77 | 85 |
| Mugil cephalus | 7 | 1 | | 6 | 5 | 4 |
| Mugil curema | | | | | | 23 |
| Ogilbia cayorum | 6 | 8 | | 1 | | |
| Opisthonema oglinum | | 3 | 1 | | | |
| Opsanus beta | 27 | 41 | 46 | 36 | 83 | 34 |
| Poecilia latipinna | 94 | 349 | 323 | 482 | 420 | 383 |
| Rivulus marmoratus | | | 1 | | | |
| Sphyraena barracuda | 13 | 12 | 8 | 11 | 12 | 22 |
| Strongula marina | | 1 | | | | 1 |
| Strongula notata | 17 | 96 | 117 | 95 | 124 | 91 |
| Strongula timucu | 1 | | | | | |
| Syngnathus floridae | | 3 | | | | 2 |
| Syngnathus scovelli | 12 | 14 | 4 | 6 | | 2 |
| Trachinotus falcatus | | 1 | | | | |
| Trinectes maculatus | 8 | 15 | 3 | | 2 | 1 |

TABLE 14. SPECIES REPRESENTED BY OVER 90 FISH PER SAMPLE MONTH
ALL NET DATA

MAY-OCT 1989

Table 14a. Upstream Locations

| SPECIES | MONTHS | | | | | |
|---|---|---|---|---|---|---|
| | MAY | JUNE | JULY | AUGUST | SEPT | OCTOBER |
| Poecilia latipinna | | | * | * | * | * |
| Floridichthys carpio | | * | * | * | * | * |
| Lucania parva | * | * | * | | | * |
| Anchoa mitchelli | * | | | | | |
| Menidia beryllina | | * | * | * | | |
| Microgobius gulosus | | * | * | * | | |
| Eugerres plumieri | | | | | * | * |
| Cichlasoma urophthalmus | | | | | | * |

Table 14b. Mid-stream Locations

| SPECIES | MONTHS | | | | | |
|---|---|---|---|---|---|---|
| | MAY | JUNE | JULY | AUGUST | SEPT | OCTOBER |
| Poecilia latipinna | | * | * | * | * | |
| Floridichthys carpio | | * | * | * | * | * |
| Anchoa mitchelli | * | | | * | * | * |
| Lucania parva | | | * | * | | |
| Menidia beryllina | | | | | * | |
| Atherinomorus stipes | | | | | * | * |
| Eucinostomus gula | | | | | | * |
| Eucinostomus harengulus | * | | | | | * |

Table 14c. Down-stream Locations

| SPECIES | MONTHS | | | | | |
|---|---|---|---|---|---|---|
| | MAY | JUNE | JULY | AUGUST | SEPT | OCTOBER |
| Lucania parva | * | * | * | * | * | * |
| Atherinomorus stipes | * | | * | * | * | * |
| Floridichthys carpio | | * | * | * | * | * |
| Menidia beryllina | | * | | | | |
| Poecilia latipinna | | | | | | * |

during four of the six months). These consistently abundant species were F. carpio and P. latipinnia. Of the more variable species, the bay anchovy was abundant only in May. The inland silverside and clown goby, however, were only abundant in June, July and August. The striped mojarra and mayan cichlid were abundant only in September and October.

At midstream locations, of eight species which were abundant during at least one month, only three were consistent: F. carpio, P. latipinnia and A. mitchelli. The first two are the same species that were consistently very dominant upstream as well. Of the more variable species, the rainwater killifish became abundant only in July and August, while inland silversides became abundant only in September. The hardhead silversides were very abundant in both September and October. While the mojarra, E. harengulus was very abundant in May and October, the silver jenny, E. gula was only dominant in October.

In contrast to the mid and upstream locations, only five species were abundant during at least one month of the study, but of these three were very abundant on a consistent basis (L. parva, A. stipes, and F. carpio). The two other species were only very abundant in one month each. Inland silversides were a dominant species early in the study period (June) and sailfin mollies were very abundant later, (October).

Enclosure Nets: Preliminary Discussion of Patterns

<u>Salinity</u>: As expected, upstream stations (Highway Creek and Joe Bay) show a much wider range of salinities than downstream and midstream. Furthermore, results of the salinity measurements indicate that for the study period May through November 1989, analogous sites in the east and west systems do not act as replicates in terms of salinity.

The eastern system apparently receives more freshwater inflow than the western system. This may be the result of more water flowing from C-111 cut-outs toward the Highway Creek system than toward Joe Bay (SFWMD personnel). The salinity data collected supports this hypothesis. However, as indicated by our pilot study results, this salinity pattern varies between years. In early December 1988, salinity in Joe Bay was 10.5 ppt, whereas in November of 1989, the salinity in the same Joe Bay location was over 30 ppt. Either a great deal more freshwater inflow is yet to occur, or the coming season may offer very high salinity conditions as the present drought continues. Hypersaline conditions could be stressful for fish in affected areas (Rutherford et al, 1989)

<u>Number of Species</u>:

<u>1) Upstream/downstream patterns</u>: The greater species richness per net sample in the mid-gradient locations (though moderate in magnitude) was not expected. We

anticipated greater diversity per net at downstream locations. In actuality, the number of species per net was least downstream. However, the number of species overall samples was greatest downstream, followed by upstream and midstream sites in decreasing order.

2) West/east patterns: The western system was significantly richer in fish species and less variable in this regard month to month.

Possible explanations for these patterns will be explored from analysis of differences in physiological tolerances and in relation to data on other environmental parameters including prop root density and features of adjacent habitats.

Abundance:

The finding of greater abundances at down- and mid-stream locations for four of six months is consistent with our hypothesis of anticipated greater fish density in areas of less variable salinity regime. Similarly, greater abundance in five of six months in the more western system is interpreted in the same manner. Our finding of peak abundances in October is also consistant with other work in the area (Schmidt 1979; Funicelli et al 1986; Thayer et al 1987; Sogard et al 1989).

A preliminary density estimate, at present excluding adjustments due to small variations in area, of 2.4 fish per square meter is low in comparison with the western Florida

Bay study average of 8.0 fish per square meter in analogous prop root habitat (Thayer et al 1987). Other studies have shown generally lower fish productivity in the eastern than the western bay (Schmidt 1979; Funicelli et al 1986; Sogard et al 1989). Further refinements of our density estimates are warranted based on species-specific recovery efficiencies derived from further rotenone efficiency testing.

Species Composition:

Small, schooling fishes found in the water column appear to dominate the fish community in abundance in all locations and over the entire study period. Up, mid and downstream locations, however, are each characterized by a uniquely dominant species. More benthic species are also dominant throughout northeast Florida Bay but appear to be more uniform in their species composition in both location and season than water column species.

A much more consistent community appears to occur downstream than in upstream and midstream locations. The same species dominate downstream locations throughout the year, while species seem to replace one another in dominance in the up- and mid- stream locations.

To determine how the species composition of the study area may relate to salinity, the tolerance of each species was identified on a preliminary basis using Robins et al (1986) as the primary source of information (Table 15). The

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TABLE 15.
PRELIMINARY SALINITY PREFERENCE ANALYSIS

ALL MONTHS BIG NET MAY-OCT 1989

| UNKNOWN | FRESHWATER | EURYHALINE TENDING TO FRESHWATER | EURYHALINE | EURYHALINE TENDING TO FULLY SALINE | FULLY SALINE |
|---|---|---|---|---|---|
| | | | | Atherinomorus stipes | |
| | | | | Anchoa mitchelli | |
| | | | | Floridichthys carpio | |
| | | | Lucania parva | | |
| | | Menidia beryllina | | | |
| | | | Poecilia latipinna | | |
| | | Microgobius gulosus | | | |
| | | Eucinostomus harengulus | | | |
| | | Eugerres plumieri | | | |
| | | Strongula notata | | | |
| | | Cichlasoma urophthalmus | | | |
| | | | Gambusia sp. | | |
| | | | | Eucinostomus gula | |
| | | | | Opsanus beta | |
| | | | | | Gobiosoma robustum |
| | | | Lophogobius cyprinoides | | |
| Gobiosoma bosci | | | | | |
| | | | Gerres cinereus | | |
| | | | Sphyraena barracuda | | |
| | | | Lutjanus griseus | | |
| | | Fundulus confluentus | | | |
| | | Syngnathus scovelli | | | |
| | | Fundulus grandis | | | |
| | | Cyprinodon variegatus | | | |
| | | Trinectes maculatus | | | |
| | | Mugil cephalus | | | |
| | | Mugil curema | | | |
| | | Eucinostomus melanopterus | | | |
| | | | | Ogilbia cayorum | |
| | | | Guntherichthys longipenis | | |
| | | | Chasmodes saburrae | | |
| | | | Syngnathus floridae | | |
| | | Beloneson belizanus | | | |
| | | | | Opisthonema oglinum | |
| | | | Centropomus undecimalis | | |
| | | | Lobotes surinamensis | | |
| | | | | Arius felis | |
| Hippocampus zosterae | | | | | |
| | | | Micrognathus criniger | | |
| | | | Strongula marina | | |
| Gobiesox strumosus | | | | | |
| | | | | | Harengulus jaguana |
| | Lepomis macrochirus | | | | |
| | Lucania goodei | | | | |
| | | | | Lutjanus apodus | |
| | | | Rivulus marmoratus | | |
| | | | Strongula timucu | | |
| | | | | | Trachinotus falcatu |

FROM Robins et al 1986.

number of primary freshwater species collected was two, the bluegill (Lepomis macrochirus) and bluefin killifish (Lucania goodei). The number of saltwater fishes was three, permit (Trachinotis falcatus), scaled sardine (Harengulus jaguana), and code goby (Gobiosoma robustum). Based on this preliminary search, no information was available for three of the species collected.

All others collected are euryhaline fishes. Those tending toward lower salinity conditions numbered 15 species, and toward more saline conditions, 9 species. Those which span the entire range of fresh to fully saline conditions were 10. Those fishes that are primarily found in mid-salinity ranges numbered 4.

Thus, the study area is clearly dominated by euryhaline fishes. Those tending to prefer fresher conditions (17) were somewhat more prevalent than those species with more saline tendencies (12).

Finally, the species composition analysis shows that the northeast Florida Bay area is dominated by fishes that are important as a forage base for wading birds (8 of the fish species collected) and as prey for larger fishes (20 of the species collected). Furthermore, eight of the species collected are important commercial and recreational fishes for man.

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Appendix 10. SWIM studies in Biscayne Bay, Biological and Water Quality Studies Manatee Bay/Barnes Sound



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88-036-0649

CONTRACT

BETWEEN THE

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

AND

METROPOLITAN DADE COUNTY

This **CONTRACT** is entered into on __________________, 198___, between the South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, Florida, a public corporation of the State of Florida (**DISTRICT**), and Metropolitan Dade County, Suite 1310, 111 N.W. 1st Street, Miami, Florida 33128-1917 (**COUNTY**);

WITNESSETH:

WHEREAS, the **DISTRICT** and the **COUNTY** wish to implement a program for the improvement and management of Biscayne Bay and its tributaries;

NOW, THEREFORE, in consideration of the benefits flowing from each to the other, the parties agree as follows:

1. Unless extended or terminated, the period of performance of this **CONTRACT** shall commence on the date of execution, and extend for a period of twelve (12) months.

2. As full consideration for providing the goods and services required by this **CONTRACT**, the **DISTRICT** shall pay the **COUNTY** an amount not to exceed Four Hundred and Fifty Thousand Dollars ($450,000) as set forth in Exhibit "A" attached and made a part of this **CONTRACT**. The **COUNTY** understands and acknowledges that this CONTRACT is subject to the **DISTRICT** obtaining funding from the State of Florida pursuant to Chapter 87-97, Laws of Florida. If the **DISTRICT** does not receive such funding, this **CONTRACT** shall be null and void and neither party shall have any obligation to the other hereunder.

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3. The **COUNTY** fully understands and agrees that the **DISTRICT** shall not pay for any obligation or expenditure made by the **COUNTY** prior to the effective date of this **CONTRACT**, unless authorized in writing by the **DISTRICT**.

4. The **COUNTY** shall, to the satisfaction of the **DISTRICT**, fully and timely perform all work items described in the Scope of Work, attached as Exhibit "A".

5. The Project Managers for the **DISTRICT** and for the **COUNTY** are as follows:

| | **DISTRICT** | **COUNTY** |
|---|---|---|
| Name: | Michael Slayton | Carlos Espinosa |
| Street: | 3301 Gun Club Rd. | Suite 310, 111 NW 1st Street |
| | P.O. Box 24680 | |
| City: | West Palm Beach | Miami |
| State: | Florida | Florida |
| Zip: | 33416-4680 | 33128-1971 |
| Tel: | 305-686-8800 | 305-375-3376 |

The parties shall direct all matters arising in connection with the performance of this **CONTRACT** to the attention of the Project Managers for attempted resolution or action. The Project Managers shall be responsible for overall coordination and oversight relating to the performance of this **CONTRACT**.

6. All notices to the **COUNTY** under this **CONTRACT** shall be in writing by certified mail and sent to Carlos Espinosa. All notices to the **DISTRICT** under this **CONTRACT** shall be in writing and sent to:

South Florida Water Management District
Attn: Division of Procurement and Contract Administration
P.O. Box 24680
3301 Gun Club Road
West Palm Beach, FL 33416-4680

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The **COUNTY** shall also provide a copy of the notice to the **DISTRICT'S** Project Manager. All notices or written communications which may be required by this **CONTRACT** shall be considered delivered upon receipt. Either party may change its address by providing prior written notice to the other of any change of address.

7. All invoices submitted by the **COUNTY** shall reference the **DISTRICT'S** Contract Number 88-036-0649 and shall be directed to the Contract Administrator. The **COUNTY** shall submit the invoices on a quarterly basis to the **DISTRICT'S** Division of Procurement and Contract Administration. The **DISTRICT** shall pay the full amount of the invoice within thirty (30) days of receipt and acceptance provided the **COUNTY** has performed the work according to the terms and conditions of this **CONTRACT**. The pay schedule and deliverables are listed on Exhibit "B" attached and made a part of this **CONTRACT**.

8. The **COUNTY** shall not assign, delegate, or otherwise transfer its rights and obligations as set forth in this **CONTRACT** without the prior written consent of the **DISTRICT**.

9. To the extent permitted by Florida law, the **COUNTY** shall defend, indemnify, save, and hold the **DISTRICT** harmless from any and all claims, suits, judgments and liability for death, personal injury, or property damage arising directly or indirectly from the performance of this **CONTRACT** by the **COUNTY**, its employees, subcontractors or assigns, including legal fees, court costs, or other legal expenses. The **COUNTY** acknowledges that it is solely responsible for compliance with the terms of this **CONTRACT**, including ensuring the safety of the premises upon which this **CONTRACT**, is to be performed, and agrees to defend and indemnify the **DISTRICT**, as stated above, against all claims involving alleged negligence by the **DISTRICT** in failing to adequately ensure the safety of such premises or supervise compliance with the terms of this **CONTRACT**.

10. If either party initiates legal action including appeals, to enforce this **CONTRACT**, the prevailing party shall be entitled to recover a reasonable attorney's fee, based upon the fair market value of the services provided.

11. Workers' Compensation insurance is required for all individuals and contractors doing work for the **DISTRICT**. Coverage shall be for Statutory Limits as stipulated under applicable state and federal laws. The policy shall include Employer's Liability.

Comprehensive General Liability insurance shall have minimum limits of $300,000.00 Per Occurrence, Combined Single Limit for Bodily Injury Liability and Property Damage Liability. This shall include Premises and Operations, Independent Contractors, Products, Completed Operations and a Contractual Liability Endorsement.

The **DISTRICT** is to be included as an Additional Insured under those coverages shown in Sections of this document.

Current valid insurance policies meeting the requirement herein identified, shall be maintained during the duration of the named project.

There shall be a thirty day (30) notification to the Division of Procurement and Contract Administration, of the **DISTRICT**, in the event of cancellation or modification of any stipulated insurance policy. An approved copy of said certificate shall be on file at the **DISTRICT'S** Division of Procurement and Contract Administration during the life of this **CONTRACT**.

12. The **COUNTY** shall maintain records of all accounts, invoices for reimbursable expenses, and supporting documentation for any research or reports, for a period of five years from completing performance of this **CONTRACT**. Such records shall be sufficient to permit a proper pre and post audit in accordance with general accounting methods. The **COUNTY** shall permit the **DISTRICT** or its

designated agent to inspect such records at the location where they are kept upon reasonable prior notice.

13. If through any cause, the **COUNTY** shall fail to fulfill in timely and proper manner its obligations under this **CONTRACT**, the **DISTRICT** shall thereupon have the right to terminate this **CONTRACT** by giving written notice to the **COUNTY** of such termination and specifying the effective date thereof. In that event, all items or materials furnished by the **DISTRICT** and any unfinished reports, notes, or field data prepared by the **COUNTY** shall be returned to the **DISTRICT** and the **COUNTY** shall be entitled to receive just and equitable compensation for any satisfactory work or services completed under this **CONTRACT**, up to the amount then appropriated.

14. Pursuant to section 287.055(6), F.S., the **COUNTY** warrants that it has not employed or retained any person, other than a bona fide employee working solely for the **COUNTY**, to solicit or secure this **CONTRACT**; that it has not paid or agreed to pay any person, other than a bona fide employee working solely for the **COUNTY**, any fee, commission, percentage, gift, or other consideration contingent upon or resulting from the awarding or making of this **CONTRACT**. For breach of this provision, the **DISTRICT** may terminate this **CONTRACT** without liability and, at its discretion, deduct or otherwise recover the full amount of such fee, commission, percentage, gift, or other consideration.

15. The **COUNTY** shall assure that no person shall, on the grounds of race, color, creed, national origin, handicap, or sex, be excluded from participation in, denied the benefits of, or otherwise subjected to discrimination in any activity under this **CONTRACT**. The **COUNTY** shall take all measures necessary to effectuate these assurances.

16. The term of this **CONTRACT** may be extended only with the written approval of the parties. Unless otherwise provided, the total length of this **CONTRACT**, as extended, shall not exceed a period of three years.

17. This **CONTRACT** states the entire understanding between the parties and supersedes any written or oral representations, statements, negotiations, or agreements to the contrary. The **COUNTY** recognizes that any representations, statements or negotiations made by **DISTRICT** staff do not suffice to legally bind the DISTRICT in a contractual relationship. This **CONTRACT** shall bind the parties, their assigns, and successors in interest.

The parties or their duly authorized representatives hereby execute this **CONTRACT** on the date written above.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT,
BY ITS GOVERNING BOARD

By: ______________________________
Chairman

METROPOLITAN DADE COUNTY

By: ______________________________
Title

EXHIBIT "A"

SECTION 1 - SCOPE OF SERVICES

A. GENERAL PROVISIONS

The **COUNTY** shall perform and render as an independent contractor the services described herein. These services shall be known as the Biscayne Bay and Tributaries Improvement and Management Program. This program shall conform substantially to the description contained in the attached Exhibit "A". The program is divided into two projects as follows:

PROJECT I: Biscayne Bay and Tributaries Water Quality and Habitat Monitoring Programs.

The primary goals of the Biscayne Bay monitoring program are to 1) augment baseline water quality and habitat data on Biscayne Bay and its tributaries 2) detect and describe trends in water quality and Bay habitats both geographically and over time, 3) complement other baseline studies of the Bay and adjoining water bodies, 4) assess the impact of storm water drainage on water quality, and 5) contribute to a basis of knowledge from which regulatory policy can be made.

Currently, fifty-five sampling stations in Biscayne Bay and the Miami River are monitored on a monthly basis. Nineteen new stations in Bay tributaries will be added to the monthly sampling regime. The existing and proposed stations for this agreement are shown on Figures 1a, 1b and 1c. Additionally, the impact of stormwater drainage will be assessed by intensive synoptic sampling of specific canals and outfalls following storm events. Quarterly habitat monitoring will continue at twelve stations in Biscayne Bay. Parameters, frequency of collection and depth at which these samples will be collected are shown in Table 1. A Quality Assurance Project Plan, which follows U.S. Environmental Protection Agency and the Florida Department of Environmental Regulation guidelines, is on file with DER.

Raw data will be checked for accuracy. Conductivity and temperature data will be converted to salinity values and raw dissolved oxygen values will be corrected for temperature and salinity. The data will be stored on hard and floppy discs in an IBM personal computer. The data will be processed on a calendar year basis and the following minimum statistics are produced: mean, median, mode, standard deviation, range, N. All computerized data sets shall be made available to the **DISTRICT**.

At the close of the calendar year, the data for that year will be processed. The results will be interpreted and summarized in a report. Although the report is primarily technical in nature it will be made available to the public.

Estimated budget for the above:

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Salaries and Fringe

Biologist 2 (approx. 200 days @ $160/day) $32.000

Laboratory Materials/Services

HRS laboratory (approx. 1800 analyses) $9,675

DERM laboratory (professional services, materials and supplies)

| Parameter | Cost | Analyses/Yr | Annual |
|---|---|---|---|
| color | $11 | 888 | $ 9,768 |
| TNR | 23 | 888 | 20,424 |
| turbidity | 8 | 888 | 7,104 |
| NOx-N | 19 | 600 | 11,400 |
| NH3-N | 19 | 600 | 11,400 |
| P04 total | 11 | 600 | 6,600 |
| Chlorophyll a | 34 | 48 | 1,632 |
| Pheophytin | 34 | 48 | 1,632 |
| Cadmium | 26 | 174 | 4,524 |
| Copper | 26 | 174 | 4,524 |
| Lead | 26 | 174 | 4,524 |
| Zinc | 19 | 174 | 3,306 |
| | | TOTAL | 86,838 |

TOTAL + 10% quality assurance $95,522

Field Equipment And Supplies

Boat fuel (approx. $150/mo.) 1,800
Maintenance & repair 600

Computer Costs

Software, expendable materials 1,000

TOTAL $140,597

B. LONG-TERM EPIBENTHIC HABITAT MONITORING

1. Record the following abiotic parameters at each station on a quarterly basis simultaneously with biological monitoring: This should be consistent with prior efforts.

   a. depth
   b. temperature
   c. salinity
   d. dissolved oxygen
   e. ph
   f. light attenuation

2. Field surveys will be conducted to describe the distribution and abundance of epiflora and epifauna at each station on a quarterly basis.

   a. Epifloral and epifaunal abundance and % cover will be recorded along a 50m transect line using the line-intercept method at each station (record number and proportionate length of seagrass beds, seaweeds, sponges, coral colonies, sand, rock etc., falling directly under the line).

   b. Three one-meter-squared quadrant stations will be established along each transect to quantitatively measure seagrass density, abundance and diversity of epifauna and epiflora, and percent of bottom cover.

      1. A portable square meter grid marked off in 25 subunits will be used to randomly count epiflora and epifauna at each grid site. At least five random numbers drawn from random numbers tables will identify the grid coordinates to be sampled.

      2. Total percent of substrate cover will be estimated within each grid.

      3. Grid photographs will be used when environmental conditions permit.

3. Annual Report

   The annual report will include a description of sites and map showing station locations, results of quantitative and qualitative sampling, discussion of relative abundance, distribution and seasonality of biota, and applications to regulatory and management issues.

4. Estimated Budget

   <u>Salary and Fringe</u>

| | |
|---|---|
| Biologist (78 days @ $160/day) | $12,480 |
| <u>Miscellaneous Equipment</u> | |
| Fuel, markers, materials for transects, waterproof paper, etc. | 520 |
| TOTAL | $13,000 |

C. STORM EVENT MONITORING

1. Synoptic Water Quality Monitoring in Specified Tributaries

   Little River, Wagner Creek, and Biscayne Canal will be the site of intensive synoptic water quality monitoring following storm events. This sampling should only be made during significant flow. At each tributary, not less than fifteen water samples will be collected and analyzed for basic parameters including temperature, salinity, ph, dissolved oxygen, inorganic nutrients, turbidity, suspended solids, color, and total and fecal coliform bacteria.In addition, water or sediment shall be collected and analyzed for selected trace metals, hydrocarbon fractions, and chemical and microbial indicators of sewage contamination as necessary unless waived by the **DISTRICT** PROJECT MANAGER.

2. Outfall Monitoring

At each stormwater outfall improved by Dade County as part of the Biscayne Bay and Miami River Restoration and Enhancement Program, an automatic water sampling device will be installed prior to retrofittings. Sampling will be triggered automatically in response to flow rates or water levels in the drainage system and may continue at distinct intervals or be integrated over the course of the storm event. Samples will be analyzed for many of the basic parameters listed above, trace metals, and various hydrocarbon fractions. Sample would be collected before and after retrofitting as feasible within limits of the retrofitting construction schedule.

3. Data Management and Analysis

The data will be stored and analyzed using an IBM Personal Computer as described for the monthly water quality monitoring program. All data collected as part of the program will be available to the South Florida Water Management District.

4. Report

At the close of the funding year, the storm event data will be analyzed and compared to other available water quality data to assess the impact of storm drainage on the tributaries and Biscayne Bay. Results will be used in prioritizing outfall improvements, evaluating the effectiveness,.of previous improvements, and developing additional strategies for enhancing surface water quality.

5. Estimated Budget

a. Permanent Equipment

| | |
|---|---|
| 2 sets automatic sampling equipment @ $8.000 each | $16,000 |
| 2 field meters and pumps | 15,000 |

b. Salary and Fringe

| | |
|---|---|
| Pollution Control Inspectors and/or Biologists (30 days/outfall and 36 days/tributary at $160/day) | 31,680 |

c. Consultant Laboratory Costs

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| PARAMETER | COST/SAMPLE |
|---|---|
| NH3-N | $24 |
| NOx-N | 24 |
| Total P | 12 |
| Suspended Solids | 20 |
| Trace Metals | 100 |
| Total Hydrocarbon | 180 |
| COD | 20 |
| BOD | 20 |
| TOTAL | $410/sample |

For Outfalls: 8 discreet samples will be collected over the course of 1 to 3 storm events to determine optimum protocol for collection of composite samples. Composite samples will then be collected during at least 3 events before and 4 events following retrofitting. Duplicate analysis will be performed on 10% of the samples for quality assurance. Total cost per outfall - $13,810.

TOTAL COST FOR THREE OUTFALLS $41,430

For Tributaries: 15 samples will be collected synoptically at one of three tributaries during two separate storm events. Remaining tributaries will be sampled on separate occasions. Duplicate analysis will be performed on 10% of the samples for quality assurance.
Total cost per tributary - $13,365

TOTAL COST FOR THREE TRIBUTARIES $40,095

d. Miscellaneous Supplies

| | |
|---|---|
| Hardware, computer costs, fuel, expendable equipment, etc. | 2,200 |
| TOTAL | $146,405 |
| Total Annual Cost of Monitoring Tasks | $300,002 |

PROJECT II: Pollution Control Enforcement

One full-time **COUNTY** pollution Inspector is currently assigned to enforce environmental regulations and respond to citizen complaints along the Miami River and its associated drainage area. The scope and intensity of this activity will be increased by adding two additional full-time pollution control inspectors to conduct enforcement activities in the Miami River area and other areas of the Bay and its tributaries.

Detailed tasks for the enforcement are as follows:

Tasks

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1. Identify pollution sources along Bay tributaries and their associated drainage basins, and in adjacent portions of Biscayne Bay.

2. Initiate enforcement action by responding to citizen complaints preparing reports, warning, letters, and notices of violation; and coordinate with other sections of DERM regarding permit compliance matters.

3. Coordinate resolution of cases and all matters that require joint enforcement action by DERM and federal, state or other local agencies.

4. Evaluate damages resulting from violations and make recommendations to DERM enforcement officers for penalties, damages, or expenses for settlement of cases. Participate in judicial proceedings as necessary.

5. Assist in the development of sound enforcement policies and ordinances as needed.

<u>Estimated Budget</u>
<u>Salary and Fringe</u>

One Full-time Pollution Control Inspector 2 $50,904
Two Full-time Pollution Control Inspector 1
@ $34,739 each $69,478

<u>Permanent Equipment</u>

Two Vehicles $15,000
Two MT-500 radio w/recall $3,600
Two Bailer/sampler (Teflon) 400
Two Camera (35mm w/50mm lens #80-210mm telephoto) 800
Two Sets miscellaneous safety equipment 600

<u>Miscellaneous Services</u>

Secretary of State,
Certified Corp. Records 200
Film & Developing 500
Sampling - lab costs $30,000

Total Estimated Budget $171,482*

* Dade County DERM shall not be reimbursed for amounts over $150,000.

B. <u>Responsibilities of the COUNTY</u>

1. The **COUNTY** shall be responsible for implementing the project.

2. When necessary, the **COUNTY** shall select contractors and consultants, in accordance with State law and County ordinance to perform the project activities.

3. The **COUNTY** shall prepare any necessary subcontracts for services. Such contracts and amendments thereto in excess of $10.000 shall be reviewed by the **DISTRICT** prior to execution by the **COUNTY**.

4. The **COUNTY** shall provide the **DISTRICT** with a copy of all executed contracts within thirty days of the execution of such contracts.

5. The **COUNTY** may elect to perform any or all portions of the project without the use of contractors or consultants.

6. The **COUNTY** as it deems necessary, will review performance of subcontractors and allow the **DISTRICT** to inspect the project activity to ensure adherence to the requirements of this Agreement. Upon completion of the work performed under a contract, the **COUNTY** shall certify to the **DISTRICT** in writing, that the work has been fully and satisfactorily performed in accordance with the requirements of this Agreement.

C. <u>Responsibilities of the **DISTRICT**</u>

The **DISTRICT** shall coordinate and cooperate with the **COUNTY** throughout implementation of the project.

**EXHIBIT "B"**
**Payment and Deliverable Schedule**

THE **DISTRICT** shall pay the **COUNTY** lump sums for reimbursement of the project cost, not to exceed four hundred and fifty thousand dollars. This shall be broken down into two parts. The amount for the monitoring program shall not exceed $300,000.00 and the amount for the Enforcement program shall not exceed $150,000.00. Invoices with supporting documents shall be submitted by the **COUNTY** to the **DISTRICT** quarterly. Certification of satisfactory completion of activities specified in Attachment A shall be submitted by the **COUNTY** for acceptance by the **DISTRICT**.

The invoices should follow the following format:

All invoices to list the Contract Number 88-036-0649 Costs for the monitoring and enforcement programs to be listed separately.

The period of the invoice to be indicated.

Sufficient back up data shall be included to justify expenses billed.

Invoices for equipment must include copies of invoices or billings received by the **COUNTY**.

**SCHEDULE OF WORK**

This contract shall become effective on the date of execution and shall remain in effect for a period of one year. The contract can be extended by mutual agreement. The **COUNTY** shall work as expeditiously and as feasible, however the monitoring and enforcement is expected to cover the entire year of the agreement. Should costs be incurred that would indicate that funds would be exhausted prior to the end of the year, the **DISTRICT** will withhold payment until the respective Project Managers have resolved the scope of work to ensure the full year of monitoring.

**REPORTS REQUIRED**

The **COUNTY SHALL SUBMIT TO THE DISTRICT** at least quarterly, reports in letter form, including maps and additional material as necessary to describe the progress of the planned and ongoing project activities. The first progress report shall be submitted the end of the first three month period following execution of this Agreement. Additional reports shall be submitted at the end of each three month period thereafter for the duration of this Agreement. Maps should be in a format compatible with the **DISTRICT'S** GIS system unless waived by the **DISTRICT** Project Manager. Data on chemical analysis to be submitted in a format compatible with the **DISTRICT'S** chemical data base.

Reports

Quarterly reports must accompany quarterly invoices. The reports for the monitoring phase must include the information outlined in Exhibit "A". The reports for the enforcement phase of the contract must include the following data:

1) Number of cases
2) Name and location of the violations
3) Nature of the violation
4) The enforcement act
5) The next step involved
6) A status update on the last quarter

The **COUNTY** shall submit the final report summarizing the activities undertaken to fulfill this Agreement, no later than three months following project completion. The final report shall include a computerized record of all water quality data collected during the project.

I. **PRIORITY WATERBODY** Biscayne Bay

II. **PROJECT TITLE:** Pesticide Sediment Monitoring

III. **DESCRIPTION:** This project was developed to screen sediments in the South Dade Tributary canals for Pesticides, PCBs, PAHs, and other synthetic organic chemicals. It is being carried out by Metro-Dade County DERM and is a companion project to a sediment screen for various metal contamination begun in FY 87-88. The result of this work will be a characterization of contaminants in the mouth of tributary canals in South Biscayne Bay. This work is designed in a stepwise manner. Phase I sampling is designed to characterize the contaminant content of these sediments and phase II is designed to utilize this information. Phase II will either target testing for specific compounds to determine their extent and concentration, or will target a broadly contaminated canal depending on the results of Phase I testing. This information will provide a data base for the direction of future organic contaminant analyses in this region.

IV. **PROGRESS TO DATE:** The first set of sediment samples have been collected and analyzed. Dade County DERM has not yet received the results of this work.

V. **PROGRESS IN 1990:** The analysis will be completed and a set of data will be available to determine the future direction for sampling of this type in South Biscayne Bay. This contract is for $50,000

## EXHIBIT "A"

## SECTION 1 - SCOPE OF SERVICES

### A. GENERAL PROVISIONS

The **COUNTY** shall perform and render as an independent contractor the services described herein. These services shall be known as the Biscayne Bay and Tributaries Improvement and Management Program (the "Program"). The Program is divided into two projects as follows:

PROJECT I: Biscayne Bay and Tributaries Water Quality and Habitat Monitoring Programs.

The primary goals of the Biscayne Bay monitoring program are to 1) augment baseline water quality and habitat data on Biscayne Bay and its tributaries; 2) detect and describe trends in water quality and Bay habitats both geographically and over time; 3) complement other baseline studies of the Bay and adjoining water bodies; 4) assess the impact of storm water drainage on water quality; and 5) contribute to a basis of knowledge from which regulatory policy can be made.

Currently, fifty-five sampling stations in Biscayne Bay and the Miami River are monitored on a monthly basis. Nineteen new stations in Bay tributaries will be added to the monthly sampling regime. The existing and proposed stations for this Contract are shown on Figures 1a, 1b and 1c. Additionally, the impact of stormwater drainage will be assessed by intensive synoptic sampling of specific canals and outfalls following storm events. Quarterly habitat monitoring will continue at twelve stations in Biscayne Bay. Parameters, frequency of collection and depth at which these samples will be collected are shown in Table 1. A Quality Assurance Project Plan, which follows U.S. Environmental Protection Agency and the Florida Department of Environmental Regulation (DER) guidelines, is on file with DER.

Raw data will be checked for accuracy. Conductivity and temperature data will be converted to salinity values and raw dissolved oxygen values will be corrected for temperature and salinity. The data will be stored on hard and floppy discs in an IBM personal computer. The data will be processed on a calendar year basis and the following minimum statistics are produced: mean, median, mode, standard deviation, range, N. All computerized data sets shall be made available to the **DISTRICT**. Does this include 1979-present?

At the close of the calendar year, the data for that year will be processed. The results will be interpreted and summarized in a report. Although the report is primarily technical in nature it will be made available to the public.

Estimated budget for the above:

Salaries and Fringe

Biologist 2 (approx. 200 days @ $160/day) $32,000

Laboratory Materials/Services

HRS laboratory (approx. 1800 analyses) $9,675
DERM laboratory (professional services, materials and supplies)

| Parameter | Cost | Analyses/Yr | Annual |
|---|---|---|---|
| color | $11 | 888 | $ 9,768 |
| TNR | 23 | 888 | 20,424 |
| turbidity | 8 | 888 | 7,104 |
| NOx-N | 19 | 600 | 11,400 |
| NH3-N | 19 | 600 | 11,400 |
| P04 total | 11 | 600 | 6,600 |
| Chlorophyll a | 34 | 48 | 1,632 |
| Pheophytin | 34 | 48 | 1,632 |
| Cadmium | 26 | 174 | 4,524 |
| Copper | 26 | 174 | 4,524 |
| Lead | 26 | 174 | 4,524 |
| Zinc | 19 | 174 | 3,306 |
| | | TOTAL | 86,838 |

where are fecal & total coliforms?

TOTAL + 10% quality assurance $95,522

Field Equipment And Supplies

Boat fuel (approx. $150/mo.) 1,800
Maintenance & repair 600

Computer Costs

Software, expendable materials 1,000

TOTAL $140,597

B. LONG-TERM EPIBENTHIC HABITAT MONITORING

1. Record the following abiotic parameters at each station on a quarterly basis simultaneously with biological monitoring: This should be consistent with prior efforts.

   a. depth
   b. temperature
   c. salinity
   d. dissolved oxygen
   e. ph
   f. light attenuation

2. Field surveys will be conducted to describe the distribution and abundance of epiflora and epifauna at each station on a quarterly basis.

   a. Epifloral and epifaunal abundance and % cover will be recorded along a 50m transect line using the line-intercept method at each station (record number and proportionate length of seagrass beds, seaweeds, sponges, coral colonies, sand, rock, etc., falling directly under the line).

   b. Three one-meter-squared quadrant stations will be established along each transect to quantitatively measure seagrass density, abundance and diversity of epifauna and epiflora, and percent of bottom cover.

      1. A portable square meter grid marked off in 25 subunits will be used to randomly count epiflora and epifauna at each grid site. At least five random numbers drawn from random numbers tables will identify the grid coordinates to be sampled.

      2. Total percent of substrate cover will be estimated within each grid.

      3. Grid photographs will be used when environmental conditions permit.

3. Annual Report

The annual report will include a description of sites and map showing station locations, results of quantitative and qualitative sampling, discussion of relative abundance, distribution and seasonality of biota, and applications to regulatory and management issues.

4. Estimated Budget

<u>Salary and Fringe</u>

| | |
|---|---|
| Biologist (78 days @ $160/day) | $12,480 |

<u>Miscellaneous Equipment</u>

| | |
|---|---|
| Fuel, rarkers, materials for transects, waterproof paper, etc. | 520 |
| TOTAL | $13,000 |

C. STORM EVENT MONITORING

1. Synoptic Water Quality Monitoring in Specified Tributaries

Little River, Wagner Creek, and Biscayne Canal will be the site of intensive synoptic water quality monitoring following storm events. This sampling should only be made during significant flow. At each



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What hydrocarbons

tributary, not less than fifteen water samples will be collected and analyzed for basic parameters including temperature, salinity, pH, dissolved oxygen, inorganic nutrients, turbidity, suspended solids, color, and total and fecal coliform bacteria. In addition, water or sediment shall be collected and analyzed for selected trace metals, ~~hydrocarbon~~ fractions, and chemical and microbial indicators of sewage contamination as necessary unless waived by the **DISTRICT** PROJECT MANAGER.

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2. Outfall Monitoring

At each stormwater outfall improved as part of the Biscayne Bay and Miami River Restoration and Enhancement Program, an automatic water sampling device will be installed prior to retrofittings. Sampling will be triggered automatically in response to flow rates or water levels in the drainage system and may continue at distinct intervals or be integrated over the course of the storm event. Samples will be analyzed for many of the basic parameters listed above, trace metals, and various hydrocarbon fractions. Sample would be collected before and after retrofitting and should be sampled, as feasible within limits of the retrofitting construction schedule.

3. Data Management and Analysis

The data will be stored and analyzed using an IBM Personal Computer as described for the monthly water quality monitoring program. All data collected as part of the program will be available to the South Florida Water Management District.

4. Report

At the close of the funding year, the storm event data will be analyzed and compared to other available water quality data to assess the impact of storm drainage on the tributaries and Biscayne Bay. Results will be used in prioritizing outfall improvements, evaluating the effectiveness, of previous improvements, and developing additional strategies for enhancing surface water quality.

5. Estimated Budget

a. Permanent Equipment

| | |
|---|---|
| 2 sets automatic sampling equipment @ $8,000 each | $16,000 |
| 2 field meters and pumps | 15,000 |

b. Salary and Fringe

| | |
|---|---|
| Pollution Control Inspectors and/or Biologists (30 days/outfall and 20 days/tributary at $160/day) | 24,000 |

c. Consultant Laboratory Costs

| PARAMETER | COST/SAMPLE |
|---|---|
| NH3-N | $24 |
| NOx-N | 24 |
| Total P | 12 |
| Suspended Solids | 20 |
| Trace Metals | 100 |
| Total Hydrocarbon | 180 |
| COD | 20 |
| BOD | 20 |
| TOTAL | $410/sample |

Fecal + Total coliforms ?

For Outfalls: 8 samples will be collected over the course of each event. At least 3 events before and 3 events following retrofitting will be sampled. Duplicate analysis will be performed on 10% of the samples for quality assurance. Total cost per outfall = $22,704.

TOTAL COST FOR THREE OUTFALLS $68,112

For Tributaries: 15 samples will be collected synoptically at each tributary during three separate storm events. Duplicate analysis will be performed on 10% of the samples for quality assurance. Total cost per tributary = $7,097.

TOTAL COST FOR THREE TRIBUTARIES $ 21,291

d. Miscellaneous Supplies

| | |
|---|---|
| Hardware-computer costs, fuel, expendable equipment, etc. | 2,000 |
| TOTAL | $159,403 |

Total Annual Cost of Monitoring Tasks $300,000

PROJECT II: Pollution Control Enforcement

One full-time **COUNTY** pollution Inspector is currently assigned to enforce environmental regulations and respond to citizen complaints along the Miami River and its associated drainage area. The scope and intensity of this activity will be increased by adding two additional full-time pollution control inspectors to conduct enforcement activities in the Miami River area and other areas of the Bay and its tributaries.

Detailed tasks for the enforcement are as follows:

Tasks

1. Identify pollution sources along Bay tributaries and their associated drainage basins, and in adjacent portions of Biscayne Bay.

2. Initiate enforcement action by responding to citizen complaints preparing reports, warning, letters, and notices of violation; and coordinate with other sections of DERM regarding permit compliance matters.

3. Coordinate resolution of cases and all matters that require joint enforcement action by DERM and federal, state or other local agencies.

4. Evaluate damages resulting from violations and make recommendations to DERM enforcement officers for penalties, damages, or expenses for settlement of cases. Participate in judicial proceedings as necessary.

5. Assist in the development of sound enforcement policies and ordinances as needed.

Estimated Budget
Salary and Fringe

One Full-time Pollution Control Inspector 2 $50,904
Two Full-time Pollution Control Inspector 1
@ $34,739 each $69,478

Permanent Equipment

Two Vehicles $15,000
Two MT-500 radio w/recall $3,600
Two Bailer/sampler (Teflon) 400
Two Camera (35mm w/50mm lens #80-210mm telephoto) 800
Two Sets miscellaneous safety equipment 600

Miscellaneous Services

Secretary of State,
Certified Corp. Records 200
Film & Developing 500
Sampling - lab costs $30,000

explain? 30K of miscellaneous?

Total Estimated Budget $171,482*

* Dade County DERM shall not be reimbursed for amounts over $150,000.

B. Responsibilities of the COUNTY

1. The **COUNTY** shall be responsible for implementing the project.

2. When necessary, the **COUNTY** shall select contractors and consultants, in accordance with State law and County ordinance to perform the project activities.

3. The **COUNTY** shall prepare any necessary subcontracts for services. Such contracts and amendments thereto in excess of $10,000 shall be reviewed by the **DISTRICT** prior to execution by the **COUNTY**.

4. The **COUNTY** shall provide the **DISTRICT** with a copy of all executed contracts within thirty days of the execution of such contracts.

5. The **COUNTY** may elect to perform any or all portions of the project without the use of contractors or consultants.

6. The **COUNTY** as it deems necessary, will review performance of subcontractors and allow the **DISTRICT** to inspect the project activity to ensure adherence to the requirements of this Agreement. Upon completion of the work performed under a contract, the **COUNTY** shall certify to the **DISTRICT** in writing, that the work has been fully and satisfactorily performed in accordance with the requirements of this Agreement.

C. <u>Responsibilities of the **DISTRICT**</u>

The **DISTRICT** shall coordinate and cooperate with the **COUNTY** throughout implementation of the project.

Table 1. Analytical parameters, number of stations, frequency and depth of sampling for the Biscayne Bay Water Quality Monitoring Program.

| Parameters | Number of Stations | Frequency | Depth Bay | Depth River |
|---|---|---|---|---|
| Ammonia nitrogen | 50 | mo. | mid | 5' |
| Cadmium | 29 | bimon. | surface | " |
| Chlorophyll *a* | 4 | mo. | surface | " |
| Color | 74 | " | " | 5' |
| Conductance | 74 | " | " | S,5',B |
| Copper | 29 | bimon. | " | 5' |
| Depth | 74 | mo. | N/A | N/A |
| Dissolved Oxygen | 74 | " | mid | S,5',B |
| Fecal Coliform | 74 | " | surface | surface |
| Lead | 29 | bimon. | " | 5' |
| Nitrate/nitrite nitrogen | 50 | mo. | " | 5' |
| pH | 74 | " | " | S,5',B |
| Pheophytin *a* | 4 | " | surface | N/A |
| Phosphate phosphorus | 50 | " | mid | 5' |
| Photosynthetically Active Radiance | 74 | " | S,3',B | S,3';5' |
| Temperature | 74 | " | mid | S,5',B |
| Total Coliform | 74 | " | surface | surface |
| Total Non-filterable Residue | 74 | " | mid | 5' |
| Turbidity | 74 | " | " | " |
| Zinc | 29 | bimon. | " | 5' |

S-surface, B-bottom N/A - not applicable

Analysis of fecal and total coliform samples will be conducted by Florida State Health Laboratory.